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FILE REPORT

3 STAND OBJECTIVES STUDY

Data From Unmanaged Well-stocked Forest Upland Stands in Southern Illinois

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INTRODUCTION

The purpose of this work was to study existing well-stocked but unmanaged stands to learn the best stand conditions to simulate in management and to develop at least temporary guides for optimum stocking. A basic part of such guides is the recognition and definition of site growing capacity and its relation to desirable stocking, species, basal area, and diameter distribution of uneven-aged stands. Because this growing capacity is chiefly related to topographic conditions, the term site-type rather than type will be used in this report.

Stands studied were the best looking well-stocked forests that could be found. They were fully-stocked in the sense that the land area was occupied by as many trees of the particular diameter distribution as the site would support. There was almost complete crown closure and ground reproduction was scarce but not absent. Trees in the 1-4 inch diameter class were present but not tallied. It must be emphasized that while most of the stands were fully stocked in the above sense and even attained, closely approached, or surpassed "normal" stocking, there is no evidence or claim that stands had optimum stocking. The terms full stocking and

optimum stocking are not used synonymously in this paper. Optimum stocking refers to the most advantageous numbers and diameter distribution of trees for the maximum production of a given product, usually high quality sawlogs with desirable properties for manufacture into lumber or other wood products.

The original idea was to use the selected stands as patterns for management objectives of other stands. With this in mind well-stocked, high quality (relatively), uneven diameter distribution stands were chosen and studied carefully. In general, stands were uneven-aged or two-aged although some tended to be even-aged, plus or minus 20 years. It must be emphasized that this whole study and the conclusions and recommendations reached apply to uneven-aged stands which would normally be managed by the selection method.

It was obvious, of course, that the study plots were completely unmanaged, but this point was not emphasized in the preliminary discussions or in the Working Plan. The idea of using such stands as a pattern was perhaps a new one and this point was emphasized. The crux of the problem was in finding unmanaged stands that happened to be favorably constituted and would simulate optimum stocking and show high growth rates of products desired. As it turned out, the good looking, well-stocked stands chosen for study were overstocked from the standpoint of satisfactory and uniform growth on the best quality trees. The growth capacity of the site was being dissipated on too high a total basal area of trees and diameter growth was rapidly decreasing, even on dominant and co-dominant trees.

The very great difficulty of finding unmanaged uneven-aged stands that could serve strictly as a pattern for optimum stocking was soon evident.

What we needed were well-stocked stands that had received various degrees of improvement and salvage cutting 10 to 15 years ago. These would tend to simulate managed stands and give some idea of the growth that could be expected from different residual volumes and on different sites. No such stands were located in southern Illinois. Timber sales on the National Forest were too recent and fragmentary. Most of the heavy cutting by lumbermen and tie hacks had occurred from about 1890 to 1910 and the type of cutting was highgrading of all the best timber, leaving the low value trees and undesirable species. This accounts in large part for the scarcity of good white oak and yellow poplar sawtimber and the relative abundance of hickory.

Thus, for the past 50 odd years many stands have developed nearly unhindered by cutting except for occasional light cuts for especially valuable trees. In that time they have reached the "overstocked" condition previously described. Because of past cutting practice and fire, stands in southern Illinois are also of poor quality. The stands studied, however, were much above average in quality and this factor did not materially affect the outcome of the results on the quantitative aspects of stocking. All trees were included in stocking and growth except out and out culls and these were not numerous enough to be significant.

For the reasons stated above the stands studied could not be used as patterns to copy in forest management. However, the study was very useful in many ways, as will be seen. The basic data collected and concepts evaluated are used to set up tentative goals for management on the widely diverse site qualities of the upland section of southern Illinois and similar adjacent regions.

DESCRIPTION OF STUDY

Stands Studied

All plots were located in the hilly upland region of southern Illinois, south of Highway Route 13. Figure 1 shows the location of the plots. At the beginning of the study two broad forest types were recognized, mixed hardwoods and oak-hickory. These types were based chiefly on topography rather than species composition, although composition does vary between the two types. The mixed hardwoods type occurs on coves, stream margins and north and east slopes. It is composed chiefly of yellow-poplar, white oak and black oak. The oak-hickory type occupies ridge tops and south and southwest slopes. The chief species are white oak, black oak, scarlet oak, post oak and hickory. Although the original species composition might have been a satisfactory criterion of forest type, past cutting practice has so altered this that site-types based on potential species composition and on timber growth is a far more useful concept than species composition alone. The data in this report will show the wide differences in timber carrying capacity and growth not only between these two broad site-types but also between site-types within the broad types. Such differences in timber carrying and growing capacity of unmanaged stands, because they are based on intrinsic site capacity, would have about the same relative value for managed stands.

Methods

One-fourth and one-tenth acre circular plots with a common center were laid out in the best portions of the selected stands. On both the larger and smaller plots all trees were measured and tallied as follows:

MAP OF SOUTHERN ILLINOIS

SHOWING LOCATION OF STUDY PLOTS

(1) Mixed Hardwoods type plot number.

[5] Oak-Hickory type plot number.

Figure 1

1. Species for all trees 4.6" d.b.h. and over.

2. D.b.h. for all trees 4.6" and over taken with a diameter tape.

3. Merchantable height of all trees 4.6" and over. Trees 10.6" d.b.h. and over (sawtimber) were tallied to the nearest one-half log, and trees 5.6 to 10.5" d.b.h. (poles) were tallied to the nearest four feet in intervals, 12, 16, 20, 24, 28, etc. to a 4 inch top. The ocular estimates were occasionally checked with an Abney Level.

4. Culls. All trees 4.6" and over not merchantable for anything except firewood or which will never produce at least a merchantable 8' log.

5. Dead trees, giving species, d.b.h., and merchantable height with an estimate of the possible date of death.

On the smaller inside one-tenth acre plots, the following additional data were taken on all trees 4.6" d.b.h. and over except where otherwise noted:

1. Total height of representative trees in different size classes.

2. Radial growth at breast height for the last 20 years by 5 year periods. Increment cores were measured to the nearest 1/20". All borings were taken on the side of the trees toward the plot center.

3. Radial bark thickness to the nearest 1/20" at breast height.

4. Crown class--dominant, co-dominant, intermediate, or suppressed.

5. Age of tree (where possible to get by increment borer).

6. The number of annual rings in each of the three outer 1 inch layers of wood, for all trees 13.6" d.b.h. and over.

7. Volume of each tree by log grades for all trees 13.6" d.b.h. and over. Appendix Tables 1 and 2 show completed tally forms. Appendix Tables 9 and 10 give the Forest Products Laboratory log grades used. All volumes are expressed as gross, and no effort was made to estimate the cull factor of merchantable trees.

General site data was recorded for each plot. This included aspect, percent slope, topographic position, general forest type, history and location (For a complete description of the plan of study see "Plan For Stand Objectives Study For Southern Illinois Hardwoods," by L. S. Minckler, Silviculturist, dated September 24, 1947.).

All calculations of volume, growth, and basal area and similar stand characteristics were made by standard methods. The twelve tables in the Appendix give all information and sample calculation of all the chief computations made in this report. It includes sample field data sheets, form classes used, merchantable heights, bark thicknesses, sample growth calculations, site descriptions, log grades and other data and procedures used in this report.

RESULTS

General

Table 1 is the master table of this file report. It gives a complete picture of the individual plots and the composite stands for each of the tw types. Together with footnotes, Table 1 is self-explanatory and forms the basis for a part of what follows. Some of the more important conclusions which may be drawn from this table are as follows:

1 Plo No	22 B.H. growth: ree per last r period s :Saw-T.	23 Growth per yr. bd. ft. Int. Last 10 yrs.	24 Growth per yr. bd. ft. Int. Previous 10 yrs.	25 Growth per year Cubic feet Poles	26 Growth per year Cubic feet Saw t.	27 Growth per year Cubic feet Total	28 Av. height dom. trees	29 Stand age 11/	30 Plot No.
1	.81	374	188	6.3	37.7	44.0	70	100	1
2	.63	332	420	6.8	35.0	41.8	75	100	2
3	.93	347	478	13.1	34.8	47.9	90	100	3
4	.99	489	480	8.6	64.3	72.9	92	120	4
6	.47	247	348	15.9	22.5	38.4	80	120	6
8	.57	307	308	3.3	40.2	43.5	85	150	8 Virgin
10	.66	217	232	9.7	22.2	31.9	80	70	10
11	1.28	330	430	10.7	45.6	56.3	82	80	11
16	.63	491	670	11.1	60.1	71.2	90	60	16
19	.56	248	251	5.5	25.2	30.7	75	120	19
Means 5/	.75 6/	338 (331	381 381) 9/	9.1 (7.6	38.8 37.7	47.9 45.3) 10/	82	102	
5	.47	149	158	12.0	12.9	24.9	75	120	5
7	.74	198	354	3.2	23.7	26.9	65	90	7
9	.58	286	63	4.8	13.8	18.6	60	70	9
12	.48	267	66	10.3	15.8	26.1	67	80	12
13	-	0	0	31.4	0	31.4	55	50	13
14	.55	131	187	14.4	13.2	27.6	70	100	14

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Plot No.	Number of trees								Sawtimber		Basal Area, sq. ft.			Volume Bd. ft. Int.			Volume Cubic feet			Av. D.B.H. growth per tree per last 5 year period		Growth bd. ft. per yr. Int.		Growth per year Cubic feet			Av. height dom. trees	Stand age 11/	Plot No.
	5-7"	8-10"	11-17"	18"-up	Total poles 1/	Total saw t. 2/	Culls 3/ Po.	Culls 3/ ST	Dead 4/ Po.	Dead 4/ ST	Av. Mt. height feet	Av. D.B.H. inches	Poles	Saw t.	Total	11-17"	18"-up	Total	Poles	Saw t.	Total	Poles	Saw-T.	Last 10 yrs	Previous 10 yrs.	Poles	Saw t.	Total			
														MIXED HARDWOODS TYPE															
1	56	8	44	16	64	60	8	0	0	0	26	15.1	14.6	77.6	92.2	4296	3880	8176	110	1666	1666	.61	.81	374	188	6.3	37.7	44.0	70	100	1
2	68	32	62	12	100	64	8	0	8	0	26	14.4	25.9	80.0	105.9	3880	4680	8460	177	1825	2002	.45	.63	332	420	6.8	35.0	41.8	75	100	2
3	40	40	32	12	80	44	0	0	0	0	32	16.7	26.6	78.7	104.3	3056	9500	12,556	242	1373	1614	.53	.93	347	478	13.1	34.8	47.9	90	100	3
4	32	12	24	36	44	60	4	0	0	4	34	18.2	10.6	113.6	124.2	2316	13,580	15,896	207	2621	2828	.60	.99	489	80	8.6	64.3	72.9	92	120	4
6	36	48	72	4	84	76	4	0	28	4	29	13.3	27.9	74.8	102.7	7268	884	8,152	532	1240	1772	.36	.47	247	348	15.9	22.6	38.4	80	120	6
8	28	20	40	20	48	60	8	0	0	0	33	16.7	13.0	99.0	112.0	4484	9,304	13,788	160	3470	3630	.26	.57	307	308	3.3	40.2	43.6	86	150	8 Virgin
10	36	24	52	4	60	56	12	8	0	0	30	14.0	20.2	61.2	81.4	5968	600	6,568	407	1070	1477	.33	.66	217	232	9.7	22.2	31.9	80	70	10
11	68	52	40	4	120	44	4	4	0	0	37	15.7	33.8	60.7	94.5	6568	1,084	7,652	322	1644	1966	.31	1.28	330	430	10.7	45.6	56.3	82	80	11
16	32	52	52	20	84	72	4	0	4	0	37	16.7	28.8	120.3	149.1	6772	9,416	16,188	357	2828	3185	.48	.63	491	670	11.1	60.1	71.2	90	60	18
19	36	20	72	4	56	76	0	0	0	0	30	14.4	16.2	87.3	103.5	9276	600	9,876	217	1354	1571	.30	.56	248	251	5.5	25.2	30.7	76	120	19
Means	42	29	48	13	71	61	5	1	4	1	32	15.5	20.7	84.7	105.4	5335	5,343	10,678	273	1898	2171	.41 5/	.75 6/	338 (331	381 381) 9/	9.1 (7.6	38.8 37.7	47.9 45.3) 10/	82	102	
														OAK-HICKORY TYPE															
5	66	40	56	0	96	56	4	0	8	0	25	13.2	30.3	54.4	84.7	5112	0	5112	470	826	1296	.23	.47	149	158	12.0	12.9	24.9	75	120	5
7	52	24	68	0	76	68	4	4	0	0	23	12.8	22.2	61.1	83.3	5388	0	5388	222	1006	1228	.28	.74	198	354	3.2	23.7	26.9	65	90	7
9	8	40	68	0	48	68	0	4	4	0	22	12.0	21.2	53.7	74.9	4592	0	4592	221	637	858	.34	.58	286	63	4.8	13.8	18.6	60	70	9
12	68	60	56	0	128	56	4	0	12	0	25	12.9	39.8	62.2	92.0	4652	0	4662	494	775	1269	.27	.48	267	66	10.3	15.8	26.1	67	80	12
13	136	68	4	0	204	4	4	0	0	0	24	11.0	55.3	2.8	57.9	224	0	224	843	0	843	.55	-	0	0	31.4	0	31.4	55	50	13
14	76	60	44	0	136	44	0	0	4	0	24	13.8	42.8	45.9	88.7	4052	0	4052	458	971	1429	.48	.55	131	187	14.4	13.2	27.6	70	100	14

1. There is a very wide variation between plots of the same forest type, i.e., mixed hardwoods or oak-hickory. This is especially true for volume, basal area, and growth. Even a casual examination shows that volume growth and basal area is very closely correlated with site as shown by the height of dominant trees in column 28 of Table 1. Growth per year as shown in column 27 varies for mixed hardwoods from 31 cu. ft. to 73 cu. ft. of total growth. For the oak-hickory type it varies from 15 to 31 cu. ft. These data are an expression of the timber carrying and growing capacity of the site, as all plots were fully-stocked (site fully occupied by trees as already explained).
2. There is a great difference between values for oak-hickory and mixed hardwood stands, as shown by the means (composite stand values). For example, basal area is 105 sq. ft. for mixed hardwoods and 75 for oak-hickory. Volume is nearly 11,000 for mixed hardwoods and less than 4000 for oak-hickory.
3. The plots show a high value for stocking, basal area and volume, but a disappointingly low board foot growth. Cubic foot growth seems to be very closely correlated with the site capacity as expressed by height of dominant trees. Actual cubic foot growth of fully-stocked stands is probably the best measure of intrinsic site capacity.
4. Stand ages are not necessarily associated with large trees, stand volume, or basal area. The differences associated with age are not nearly as marked as the differences which are associated with site. Some of the younger stands have the greatest volume and growth, and vice versa.

5. The diameter growth is low and the number of rings per inch high. This shows a closing in of the stands, resulting in a gradually decreasing diameter growth. Board foot growth the last ten years has been less than growth the previous ten years.

6. The sawtimber size trees on oak-hickory and the poor mixed hardwood sites are relatively small, even though the age is as much or greater than stands on better sites.

7. There is a very strong tendency for all values to be correlated with the site-type as shown by topography and the height of the dominant trees. Table 1 shows the difficulty of using these unmanaged stands as actual patterns for management objectives. The basic data can be used to show trends or principles and the stand objectives built up from those.

Species Composition

Tables 2 and 3 show the species composition for the composite stands of the two types. For the mixed hardwoods, yellow-poplar, white oak and black oak make up 78 percent of the board foot volume. This shows that the species composition in general is fairly satisfactory for sawtimber size trees. It could be improved by still further reducing scarlet oak and black gum in the stand. In pole sized timber the chief weakness of stand composition is in the surplus of hard maple and hickory. Because of their slow growth and low value both of these species would be reduced in correct management.

On the oak-hickory type white oak, black oak, scarlet oak and hickory make up 90 percent of the volume. This composition could be improved by reducing the scarlet oak and hickory in the stand. Improvement of species

Table 2.--Species distribution; mixed hardwoods composite stand

Species	Sawtimber size: Based on bd. ft.	Sawtimber size: Based on cu. ft.	Poles: Based on cu. ft.	Total: Based on cu. ft.
	Percent of total volume by size classes			
Yellow poplar	26.2	26.8	10.8	24.8
White oak	24.9	24.0	40.2	26.0
Black oak	27.0	27.5	3.0	24.4
Scarlet oak	4.4	4.6	3.6	4.5
N. red oak	0.9	0.9	0	0.8
Hickory	3.6	3.7	10.9	4.6
Black gum	3.4	3.5	0	3.1
Sweet gum	3.6	2.8	0	2.4
Black walnut	2.5	2.7	2.6	2.7
Black cherry	2.7	2.9	0	2.5
Elm	0.8	0.6	5.8	1.3
Hard maple	0	0	15.0	1.9
Cucumber	0	0	5.5	0.7
White ash	0	0	0.4	0.0
Sassafras	0	0	2.2	0.3

Table 3.--Species distribution; Oak-Hickory composite stand

Species	Sawtimber size	Pole size	Total stand
	Percent of total cu. ft. volume by size classes		
White oak	26.1	51.0	35.4
Black oak	52.0	20.7	40.3
Scarlet oak	14.4	9.5	12.6
Post oak	1.8	2.0	1.9
Hickory	5.7	15.0	9.2
Elm	0	0.6	0.2
White ash	0	1.2	0.4

composition should be made in both types, but this is only part of the problem in management of the existing stands of upland southern Illinois.

Site-type Classes

The concept of different site-type classes became evident in table 1. Table 4 and figure 2 separate and define the five site-type classes which are apparent from the plots which were examined. Table 4 and figure 2 show that there is a direct relationship between the site-type, as shown by the height of the dominant trees, and growth, basal area, site index, and site quality based on the mean basal area times the height of the overstory trees. It must be emphasized that all of these stands were approximately fully-stocked from the standpoint of site occupancy and crown closure. Table 4 shows that the density index varies depending upon the basis of comparison. It also shows that the poorer sites have a lower density index than the better sites. This will be discussed later. Table 4 is the basis for recognition of the five site-types which are used in this report.

The use of the height of dominant trees as a yardstick of site quality presupposes that such dominant trees are about 80 years or more in age and that height growth has ceased or is tending to level off. The shape of the site index curves shows that this can safely be done and still retain satisfactory accuracy. The shape of the top of hardwood crowns is a good indication of whether the tree has virtually ceased height growth. Large dominant trees with flat topped crowns can safely be used as height yardsticks.

Table 4.--Site quality and stand density expressed in different ways

Forest type	Plot No.	Height dominant trees	Growth per acre per year	Basal area per acre /1	Approximate age dominant trees	Site index /2	Site /3	Density index /6: Basal area /4	Density index /6: Spacing-height /5
		Feet	Cu. ft.	Sq. ft.	Years	Feet		Percent	Percent
M.H.	4	92	72.9	124.2	120	73	Very good	89	111
"	3	90	47.9	104.3	100	70	"	75	116
"	16	90	71.2	149.1	60	80	"	131	112
Means		91	64.0	129		74		98	113
M.H.	8	85	43.5	112.0	150	65	Very good	80	104
"	11	82	56.3	94.5	80	68	"	82	120
Means		84	49.8	103		67		81	112
M.H.	2	75	41.8	105.9	100	62	Good	84	115
"	6	80	38.4	102.7	120	62	Poor	77	116
"	10	80	31.9	81.4	70	68	Good	70	92
"	19	75	30.7	103.5	120	57	Medium	77	100
"	1	70	44.0	92.2	100	55	"	75	94
Means		76	37.5	97		61		77	103
O.H.	5	75	24.9	84.7	120	55	Poor	66	111
"	14	70	27.6	88.7	100	55	"	72	113
"	12	67	26.1	92.0	80	55	"	79	102
"	7	65	26.9	83.3	90	52	"	69	90
"	18	65	20.6	60.6	120	50	"	49	85
Means		68	25.2	82		54		67	100
O.H.	17	62	17.5	72.4	90	50	Poor	64	88
"	9	60	18.6	74.9	70	50	"	71	63
"	20	60	14.6	84.9	90	48	"	75	75
Means		61	16.9	77		49		70	75

/1 Trees 4.6 inches d.b.h. and over.
/2 Height at 50 years based on tallest dominants. Calculated from site index curves in USDA Tech. Bull. No. 560 by Luther Schnur.
/3 Site classes based on average basal area times average height of overstory trees as given in Publication No. 521, Wisconsin Dept. of Conservation and University of Wisconsin, by S. R. Gevorkiantz and H. F. Scholz.
/4 Based on basal areas for composite stands, table 2, USDA Tech. Bull. No. 560.
/5 Based on spacing-height ratio as compared to standards given in Publication No. 521.
/6 Trees 1-4 inches d.b.h. not included in data but used in density index by assuming this class equal in number to 5-7 inch class.

The convenience of using total height of mature dominant trees as a site yardstick is readily apparent. Moessner [1] has used it with good success on aerial photographs. If forests are to be managed according to site-type capabilities, as evidence shows they must, some more convenient measure than traditional site index (at 50 years) must be employed. The very good correlation between these two measures for the stands studied shows that little, if any, accuracy would be lost (table 4 and figure 2). Site index is probably more accurate, but total height of the flat-topped large dominant trees is more than accurate enough for the purpose employed.

Gevorkiantz [2] has developed a logical and sound approach to site evaluation based on the total height of the overstory trees times their average basal area. Like site index this is evaluated on the basis of average age of the trees involved but is independent of stand density within certain limits. Five sites were set up in southwestern Wisconsin ranging from very good to very poor. Table 4 shows that, with one exception, the southern Illinois plots when evaluated by this method correlate well with total height, site index, and total cubic foot growth.

In comparison with basal areas of the composite even-aged oak yield tables by site index classes in Schnur's U.S.D.A. Technical Bulletin No. 560 most of the present study plots were understocked. Based on the spacing-height ratios in Gevorkiantz's Publication No. 521 most of the stands were overstocked, that is, more than "normal" stocking. The growth behavior

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[1] Moessner, Karl E. 1948.
Photo classification of forest sites.
Proc. Soc. of Amer. Foresters 1948. 278-291.

[2] See footnote 3, table 4.

of the stands themselves certainly indicated that stocking was more than optimum for steady diameter growth on the crop trees. Some of the difficulty lies in the fact that density index applies chiefly to even-aged forests. Most of the present stands tended to be uneven-aged or two-aged. Both density indices tended to show that the poorer sites were understocked. This does not seem to agree with some of the observed facts. Although the density index was greater, tree diameter growth on the better sites was not decreasing as fast as on the poorer sites. The two poorer site-types had twice as many recently dead trees per acre as the three better site-types, even though the latter have a higher density index. It is difficult to escape the conclusion that there is some confounding between the site-types and ordinary density index.

Table 5 shows the relation between site-types and some of the chief stand values. These data strengthen the necessity of the site-type concept for management of the upland forests by summarizing and extending the evidence already presented in table 4.

Table 6 expresses some basic or general laws which appear to exist in fully stocked unmanaged stands. These ratios are probably rough but show the principles of how basic relationships of stands vary by sites. Such principles may be useful for the scientific management of forest stands. For example, the total growth per acre per year may be from 20 to 50 percent of the basal area, depending upon the site. On oak-hickory sites where the height of the dominants is less than 65 feet, the total growth in cubic feet is only 20 percent of the square foot basal area. On mixed hardwood sites where the dominant trees are over 80 feet in height, the total growth is 50 percent of the basal area. This trend

Table 5.--Basal area volume and growth by site-type classes

Forest type	Site-type class: Height dominant trees	Site-type class: Site index	Plots included	Mean mt. height	Average basal area	Volume: Sawtimber	Volume: Whole stand	Average d.b.h. growth last 5 yr. period: Poles	Average d.b.h. growth last 5 yr. period: Sawtimber	Growth per acre per year: Sawtimber	Growth per acre per year: Whole stand
	Feet			Logs	Sq. ft.	M. bd. ft.	100 cu. ft.	Inches	Inches	Bd. ft.	Cu. ft.
M. H.	90+	74	3, 4, 16	$2\frac{1}{4}$	129	14.9	25.4	.54	.85	442	64.0
M. H.	81-89	67	8, 11	$2\frac{1}{4}$	103	10.7	28.0	.29	.93	319	49.8
M. H.	70-80	61	1, 2, 6, 10, 19	1-3/4	97	8.2	17.0	.39	.63	284	37.5
O. H.	65-75	54	5, 7, 12, 14, 18	$1\frac{1}{2}$	82	4.6	13.0	.35	.55	179	25.2
O. H.	Less 65	49	9, 17, 20	$1\frac{1}{2}$	77	5.0	9.6	.38	.52	153	16.9

Comparison of Stand Values by Forest Site-Types
Data from Table 4

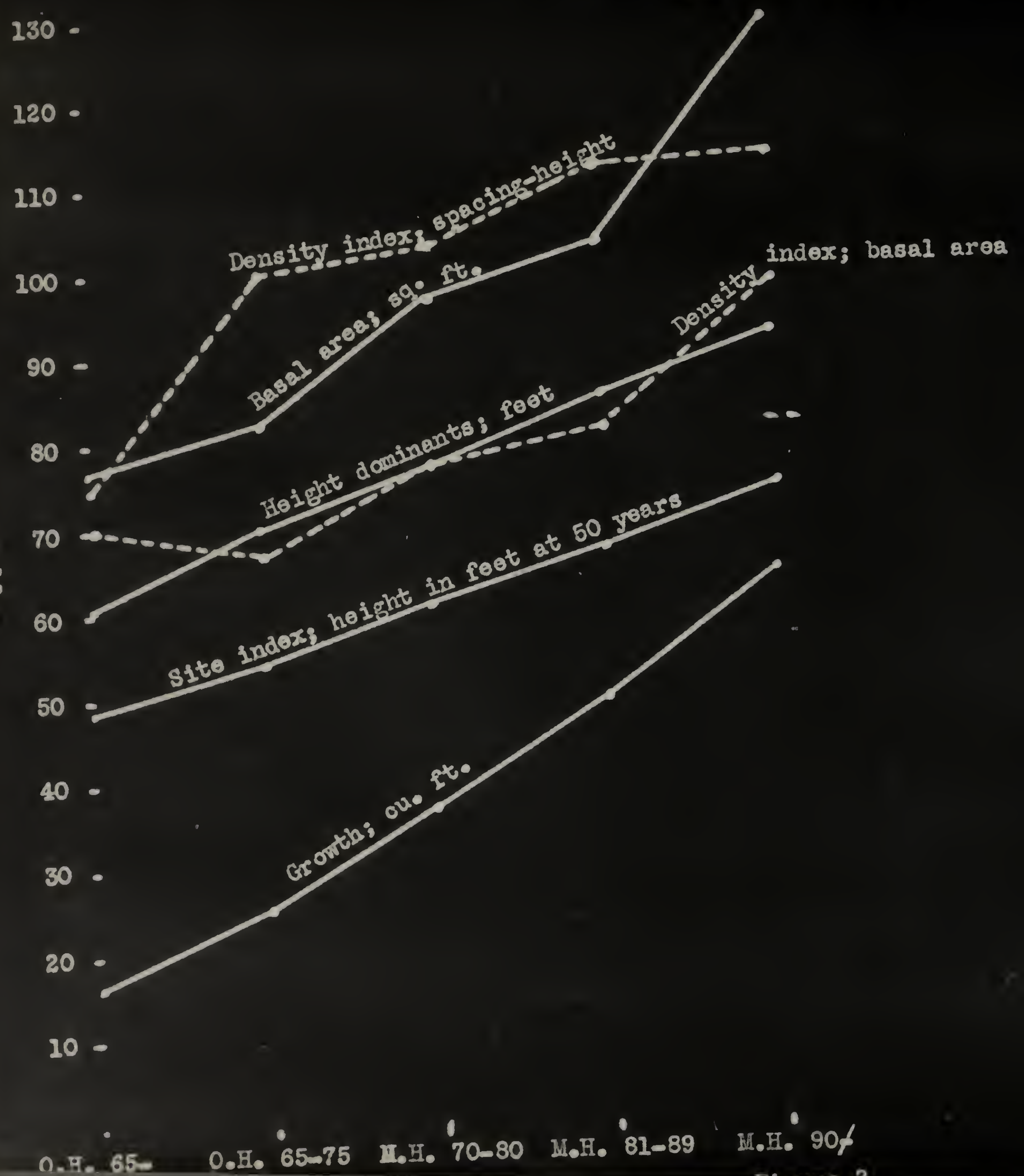

Figure 2

Table 6.--Approximate ratios; total growth and volume to basal area by site classes

Forest type	Site class. Ht. dom. trees	Ratio: total growth over basal area /1	Ratio: total volume over basal area /2	Basis. No. of tenth-acre plots
	Feet			
O. H.	Less 65	0.2	13	3
O. H.	65+	0.3	16	5
M. H.	Less 80	0.4	18	5
M. H.	80+	0.5	23	5
O. H.	Pole stands	0.5	17	2

/1 Growth expressed as cubic feet per year, basal area as square feet.
/2 Volume expressed as cubic feet, basal area as square feet.

would be expected from a knowledge of the growing capacity of sites and the physiology of plant growth. If the quantitative relationships are consistent throughout a given forest region and a statistical variance could be established, the relationships could be used by forest managers.

The ratio between volume and basal area is also striking and consistent for the five site-types. The total volume may be from 13 to 23 times the basal area, depending on the site-type. On the poorer sites the total cubic foot volume is only 13 times the basal area expressed in square feet. On the best sites the total cubic foot volume is 23 times the basal area. These relationships are so logical and so consistent that it is not possible to dismiss them. It is a quantitative measure of fundamental relationships which might be expected from purely a physiological and ecological standpoint. If the statistical variance could be established the relationships could be used in a practical way.

Diameter Growth as Related to Crown Class and Tree Size

Table 7 gives the diameter growth by species, crown classes, and d.b.h. classes, and shows at a glance that diameter growth is very highly correlated with crown class. The data indicate that within crown classes there is no relation between 10 year diameter growth and present diameter.

Table 8 shows the large differences of growth between crown classes for the two types. Dominant trees grew twice as much as the intermediates and 3 times as much as the suppressed trees. There is no question about the real differences of growth between crown classes for both general forest types.

3	24	25	26	27	28	29	30	31+
-	-	-	-	-	-	-	-	-
-	-	2.0(3)	-	-	-	-	-	1.8(1)
2.8(1)	-	-	1.2(1)	-	2.2(1)	-	1.4(1)	-
1.6(1)	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
[illegible]			1.20	-	2.20	-	1.40	1.80

TABLE 7. DIAMETER GROWTH BY SPECIES, CROWN CLASS, AND D.B.H. CLASS; WELL-STOCKED UNMANAGED STANDS

D. B. H. — INCHES OF DIAMETER GROWTH IN 10 YEARS

Species	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31+
MIXED HARDWOOD TYPE; 10 ONE-TENTH ACRE PLOTS																											
Suppressed Crown Class2/																											
Hard maple	0.7(7)1/	1.0(3)	1.2(1)	-	-																						
Hickory	0.4(2)	0.8(1)	0.3(1)	-	-																						
White oak	0.2(1)	0.3(3)	0.2(2)	0.5(2)	-																						
Yellow poplar	-	-	0.7(1)	-	1.0(1)																						
Means	0.57	0.67	0.52	0.50	1.0																						
Intermediate Crown Class3/																											
Hard maple	1.0(2)	1.0(3)	1.3(4)	1.3(4)	-	-	-	-	-																		
Hickory	-	0.6(1)	0.6(4)	-	0.3(1)	-	-	-	-																		
Black gum	-	-	-	-	-	-	-	-	1.3(1)																		
White oak	-	0.4(1)	-	0.7(5)	0.9(3)	-	0.4(1)	-	0.6(2)																		
Black and red oaks	-	-	-	-	-	-	1.7(1)	-	0.8(1)																		
Yellow poplar	-	0.6(2)	-	1.9(1)	-	0.6(1)	-	-	1.3(1)																		
Means	1.0	0.74	0.95	1.06	0.75	0.60	1.05	-	0.92																		
Codominant Crown Class4/																											
Hickory	-	-	-	-	-	1.7(1)	0.9(2)	1.0(1)	-	-	-	-	-														
White oak	-	-	-	-	1.2(1)	1.0(4)	1.2(2)	0.9(3)	-	0.9(2)	1.4(1)	1.6(2)	-														
Black and red oaks	-	-	-	-	0.9(1)	1.5(1)	1.0(1)	1.0(2)	-	1.2(1)	1.1(1)	1.3(1)	1.9(2)														
Yellow poplar	-	-	-	-	-	-	-	-	1.6(3)	1.7(2)	-	1.8(1)	-														
Black gum	-	-	-	-	-	-	1.4(1)	1.6(1)	-	-	-	-	-														
Means	-	-	-	-	1.05	1.20	1.10	1.04	1.6	1.28	1.25	1.58	1.9														
Dominant Crown Class5/																											
Hickory	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0(1)	2.4(1)	-	-	-	-	-	-	-	-	-	-	-
White oak	-	-	-	-	-	-	-	-	1.4(3)	-	0.9(1)	1.3(1)	1.1(2)	-	-	1.1(1)	1.6(1)	-	-	-	2.0(3)	-	-	-	-	-	1.8(1)
Black and red oaks	-	-	-	-	-	-	-	1.8(1)	-	2.3(2)	2.1(4)	1.5(2)	1.8(1)	1.7(3)	2.3(1)	2.4(1)	-	2.5(2)	2.8(1)	-	-	1.2(1)	-	2.2(1)	-	1.4(1)	-
Yellow poplar	-	-	-	-	-	-	-	-	-	2.0(3)	-	2.2(1)	2.3(1)	-	-	-	-	-	1.6(1)	-	-	-	-	-	-	-	-
Black gum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.1(1)	-	-	-	-	-	-	-	-	-
Means	-	-	-	-	-	-	-	1.80	1.40	2.12	1.86	1.63	1.68	1.70	1.66	1.97	1.60	2.03	2.20	-	2.00	1.20	-	2.20	-	1.40	1.80
OAK-HICKORY TYPE; 10 ONE-TENTH ACRE PLOTS																											
Suppressed Crown Class6/																											
Hickory	0.2(1)	0.5(2)	0.3(1)																								
White oak	0.6(6)	0.3(1)	0.3(1)																								
Black and red oaks	-	-	0.4(1)																								
Means	0.46	0.65	0.33																								
Intermediate Crown Class7/																											
Hickory	0.6(3)	0.5(4)	0.5(5)	0.7(1)	-	-																					
White oak	0.4(4)	0.6(5)	0.7(3)	0.4(3)	0.4(2)	0.7(1)																					
Black and red oaks	0.5(1)	-	0.6(1)	0.7(1)	1.1(2)	0.6(1)																					
Post oak	0.3(2)	-	-	-	-	-																					
Means	0.45	0.56	0.58	0.52	0.75	0.65																					
Codominant Crown Class8/																											
Hickory	-	-	1.5(1)	-	1.6(1)	0.8(2)	-	1.1(1)	0.4(1)	0.5(2)	-	-															
White oak	-	-	1.3(3)	1.0(8)	0.9(4)	1.3(2)	0.7(6)	0.8(1)	0.6(1)	-	-	-															
Black and red oaks	-	0.6(1)	1.3(2)	1.0(3)	1.0(3)	1.5(2)	0.9(6)	0.9(5)	1.3(2)	1.0(2)	0.9(1)	0.6(1)															
Post oak	-	-	-	-	0.3(1)	-	-	0.7(1)	-	-	0.6(1)	-															
Means	-	0.60	1.33	1.00	0.94	1.20	0.80	0.89	0.90	0.83	0.75	0.60															
Dominant Crown Class																											
Hickory	-	-	-	-	1.1(1)	-	-	-	-	-	-	-															
White oak	-	-	-	-	1.4(3)	1.5(1)	-	-	1.3(3)	1.0(2)	1.6(1)	-															
Black and red oaks	-	-	-	-	1.5(2)	1.4(1)	1.6(2)	2.1(2)	1.0(4)	2.2(1)	1.6(4)	1.0(3)															
Post oak	-	-	-	-	-	1.0(1)	-	-	-	-	-	-															
Means	-	-	-	-	1.38	1.30	1.60	2.10	1.13	1.40	1.68	1.00															

1/ Numbers in parentheses give the number of trees included in the growth mean.
2/ Three trees of miscellaneous species not recorded here.
3/ Five trees of miscellaneous species not recorded here.
4/ Eight trees of miscellaneous species not recorded here.
5/ Four trees of miscellaneous species not recorded here.
6/ One tree of miscellaneous species not recorded here.
7/ Four trees of miscellaneous species not recorded here.
8/ Two trees of miscellaneous species not recorded here.

Table 8.--Diameter growth as related to crown class

Crown class	Mixed hardwoods type/1				Oak-hickory type/1			
	D.b.h. growth 10 yrs.	Mean d.b.h.	Number trees	Ratio: growth over d.b.h.	D.b.h. growth 10 yrs.	Mean d.b.h.	Number trees	Ratio: growth over d.b.h.
	Inches	Inches		Percent	Inches	Inches		Percent
Dominant	1.83	18.8	44	9.7	1.36	12.5	31	10.9
Co-dominant	1.26	12.6	37	10.0	0.94	10.2	64	9.2
Intermediate	0.91	8.2	39	11.1	0.56	6.7	39	8.4
Suppressed	0.62	6.1	25	10.2	0.41	5.7	13	7.2

/1 Based on 10 one-tenth acre plots of each type.

Table 8 also shows another basic relationship which was not necessarily expected; that is, the ratio between diameter growth and d.b.h. within crown classes approaches a constant. This constant is about 10 for all crown classes in both forest types. This means, of course, that past and present growth has produced the final diameter and these quantities are parallel with crown classes. It also means that for the last ten years growth was highly correlated with growth for previous periods. In other words, trees now dominant must have tended to be dominant throughout most of their lives and the growth rate continued in about the same relationship to the growth of other crown classes. The fact that the intermediate and suppressed crown classes for oak-hickory dropped somewhat below 10 is another bit of evidence that stands on the poorer sites were experiencing greater internal competition than stands on the better sites.

A rough rule of thumb for unmanaged fully-stocked stands from table 8 is that diameter growth per tree per year <u>within crown classes</u> is 1/100 of the mean d.b.h. of the trees in that class. No attempt was made to break this relationship down into site-types, and it applies only to the composite oak-hickory and mixed hardwood stands. The rule of thumb illustrates a principle rather than stating an accurate quantitative measure.

<u>Individual Tree Growth</u>

The most conclusive evidence that stands are closing in and trees making ever decreasing diameter growth is shown in tables 9 and 10. These data are based on a growth ring analysis of all trees in the 20 plots 13.6" d.b.h. and over. The method of calculating individual tree growth is given in Appendix Table 7.

nge	Average growth of individual trees per year by indicated diameter classes			Average bd. ft. percent growth of individual trees by indicated diameter classes		
	D. B. H. Inches			D. B. H. Inches		
	Bd. ft.			Percent		
	15-17	13-15	11-13	15-17	13-15	11-13
	3.77	4.20	6.00	2.58	4.04	10.7
	21-23	19-21	17-19	21-23	19-21	17-19
	5.67	7.75	7.85	1.82	3.10	4.03
	13-15	11-13	9-11	13-15	11-13	9-11
	2.67	3.69	6.20	2.57	6.59	2/
	15-17	13-15	11-13	15-17	13-15	11-13
	3.50	3.64	6.00	2.40	3.50	10.7
	24-26	22-24	20-22	24-26	22-24	20-22
	7.21	6.54	7.80	1.47	1.61	2.38
	13-15	11-13	9-11	13-15	11-13	9-11
	4.95	5.32	8.14	4.13	7.6	-
	21-23	19-21	17-19	21-23	19-21	17-19
	5.59	7.73	7.50	1.32	2.29	2.86
	13-15	11-13	9-11	13-15	11-13	9-11
	3.50	4.80	6.22	3.37	8.57	-
	13-15	11-13	9-11	13-15	11-13	9-11
	4.42	5.33	6.59	4.25	9.52	-
	26-28	24-26	22-24	26-28	24-26	22-24
	11.6	14.4	12.1	1.96	2.93	2.98
	14-16	12-14	10-12	14-16	12-14	10-12
	3.46	6.22	9.71	2.79	9.15	-

Species	Mean present D. B. H.	Range D. B. H.	Number of trees	Mean present merchantable height	Mean present volume	Number of years to change diameter classes as indicated	Average growth of individual trees per year by indicated diameter classes	Average bd. ft. percent growth of individual trees by indicated diameter classes
	Inches	Inches		No. logs	Bd.ft.Int.	D. B. H. Inches / Years	D. B. H. Inches / Bd. ft.	D. B. H. Inches / Percent
Black oak	17	14.7-18.9	12	2	182	15-17: 13; 13-15: 10; 11-13: 8	15-17: 3.77; 13-15: 4.20; 11-13: 6.00	15-17: 2.58; 13-15: 4.04; 11-13: 10.7
Black oak	23	20.3-30.0	7	2	409	21-23: 12; 19-21: 8; 17-19: 7	21-23: 6.67; 19-21: 7.75; 17-19: 7.85	21-23: 1.82; 19-21: 3.10; 17-19: 4.03
White oak	15	13.5-16.0	6	2	160	13-16: 15; 11-13: 13; 9-11: 9	13-15: 2.67; 11-13: 3.89; 9-11: 6.20	13-15: 2.67; 11-13: 6.59; 9-11: 2/
White oak	17	16.1-18.1	5	2	182	16-17: 14; 13-15: 11; 11-13: 8	15-17: 3.50; 13-15: 3.64; 11-13: 6.00	15-17: 2.40; 13-15: 3.50; 11-13: 10.7
White oak	26	20.0-34.1	7	2½	681	24-26: 14; 22-24: 13; 20-22: 10	24-26: 7.21; 22-24: 6.54; 20-22: 7.80	24-26: 1.47; 22-24: 1.61; 20-22: 2.38
Yellow poplar	15	13.7-17.5	8	2½	173	13-16: 10; 11-13: 9; 9-11: 9	13-16: 4.96; 11-13: 5.32; 9-11: 8.14	13-16: 4.13; 11-13: 7.6; 9-11: -
Yellow poplar	23	20.2-25.7	3	3	518	21-23: 17; 19-21: 11; 17-19: 10	21-23: 5.59; 19-21: 7.73; 17-19: 7.60	21-23: 1.32; 19-21: 2.29; 17-19: 2.86
Scarlet oak	15	14.5-15.7	4	2	144	13-15: 12; 11-13: 10; 9-11: 9	13-16: 3.50; 11-13: 4.80; 9-11: 6.22	13-16: 3.37; 11-13: 8.57; 9-11: -
Northern red oak	15	14.5-15.4	2	2	128	13-15: 9.6; 11-13: 9; 9-11: 8.5	13-15: 4.42; 11-13: 6.33; 9-11: 6.59	13-15: 4.26; 11-13: 9.52; 9-11: -
Northern red oak	28	28.2	1	2½	605	26-28: 9; 24-26: 7; 22-24: 7	26-28: 11.6; 24-26: 14.4; 22-24: 12.1	26-28: 1.96; 24-28: 2.93; 22-24: 2.98
Black walnut	16	15.9	1	2	150	14-16: 13; 12-14: 9; 10-12: 7	14-16: 3.46; 12-14: 6.22; 10-12: 9.71	14-16: 2.79; 12-14: 9.15; 10-12: -
Black walnut	19	19.3	1	2½	315	17-19: 14; 15-17: 9.5; 13-15: 7	17-19: 4.71; 15-17: 6.10; 13-15: 7.14	17-19: 2.07; 15-17: 3.69; 13-16: 5.95
Black cherry	16	15.7	1	3	215	14-16: 16; 12-14: 8; 10-12: 10	14-16: 3.48; 12-14: 6.22; 10-12: 9.71	14-16: 2.79; 12-14: 9.15; 10-12: -
S. gum	16	15.7-16.0	2	2½	201	14-16: 11; 12-14: 12; 10-12: 12.5	14-16: 5.00; 12-14: 4.80; 10-12: 6.80	14-16: 3.50; 12-14: 5.65; 10-12: -
Hickory	19	19.3	1	2½	275	17-19: 17; 16-17: 13; 13-15: 13	17-19: 3.88; 15-17: 4.46; 13-15: 5.08	17-19: 1.70; 15-17: 2.62; 13-15: 4.88
B. gum	22	22.5	1	1½	256	20-22: 23; 18-20: 23; 16-18: 17	20-22: 2.22; 18-20: 1.96; 16-18: 2.41	20-22: 1.00; 18-20: 1.12; 16-18: 1.80

1/ From growth ring analyses of all trees 13.6 inches D. B. H. and over on 10 one-tenth acre plots. 82 percent of trees included in this table were dominants and 18 percent were codominant.

2/ Growth from 9 to 11 inches D. B. H. is in-growth. Growth percentages in board feet is infinity.

Table 10.--Individual tree growth by diameter class periods; well-stocked unmanaged stands; [1]

oak-hickory type

Species	Mean present d.b.h.	Range d.b.h.	No. trees	Mean merch. ht. logs	Mean present volume	No. years to change diameter classes as indicated	Average growth of individual trees per year by indicated diameter classes	Average bd. ft. percent growth of individual trees by indicated diameter classes
	Inches	Inches		No. logs	Bd. ft.	D.b.h. inches / Years	D.b.h. inches / Bd. ft.	D.b.h. inches / Percent
B. oak	15	13.9-16.6	13	2	142	13-15: 16; 11-13: 11; 9-11: 10	13-15: 2.63; 11-13: 4.40; 9-11: 5.60	13-15: 2.50; 11-13: 7.90; 9-11: [2]
W. oak	15	14.4-15.0	3	2	145	13-15: 15; 11-13: 10; 9-11: 8	13-15: 2.80; 11-13: 4.80; 9-11: 7.00	13-15: 2.70; 11-13: 8.60; 9-11: -
So. oak	15	14.5-17.1	7	2	156	13-15: 15; 11-13: 10; 9-11: 8	13-15: 2.80; 11-13: 4.80; 9-11: 7.00	13-15: 2.70; 11-13: 8.60; 9-11: -
P. oak	15	14.7	1	1	55	13-15: 25; 11-13: 17; 9-11: 15	13-15: 0.96; 11-13: 1.18; 9-11: 2.87	13-15: 1.52; 11-13: 2.74; 9-11: -
Hickory	15	14.3-16.5	3	2	155	13-15: 27; 11-13: 21; 9-11: 19	13-15: 1.56; 11-13: 2.30; 9-11: 2.94	13-15: 1.50; 11-13: 4.10; 9-11: -

[1] From stem analyses of all trees 13.6 inches d.b.h. and over on 10 one-tenth acre plots; 79 percent of trees included in this table were dominants and 21 percent co-dominants.

[2] Growth from 9 to 11 inches d.b.h. is in-growth. Growth percentage in board feet is infinity.

Tables 9 and 10 show that without exception individual trees are growing less board feet per ~~acre~~ tree per year in the last 2" d.b.h. period than in preceding 2" diameter periods. The reason for this is because it takes increasingly longer for the trees to put on a 1" layer of wood, that is, increase the diameter by 2 inches. This might normally be expected, but the difference in length of time is so great that the actual board foot growth per tree per year is less for each diameter period.

This reduction in board foot growth is not related to diameter as such. It has already been shown that there is no correlation, within crown classes, between diameter alone and diameter growth. The decreased growth is a result of increased competition and closing in of the stand, even though most of the trees were dominants and none below co-dominant.

The evidence in tables 9 and 10 indicates strongly that the stands are overstocked from the standpoint of adequate even growth on the sawtimber trees. This is true for both forest types and for all species and sizes. In terms of management it means that the growth potential of the site should be placed on fewer and better trees. In forest stands the total volume of wood produced per acre per year is probably about the same regardless of size of trees and number per acre, <u>just so long as the stand is fully-stocked and the growing space fully occupied</u>. Forest managers, however, want to place this growth on the best long boled trees. In a managed stand the diameter growth should remain about constant on sawtimber trees as they increase in size. This would produce a wood of better quality and greater density. Progressive decrease in ring width yields a more variable and less desirable wood. As this approximately constant diameter growth

would be placed on an increasingly larger ring, the total board foot growth would increase instead of decline.

Tables 9 and 10 constitute the heart of the evidence for the concept of managed vs. unmanaged stands. These data represent a condition which is found in unmanaged stands where the basal area is so high that diameter growth on the crop trees becomes less and less. It is not a desirable situation for a managed forest. It does, however, illustrate how the forest manager can control the texture and density of wood by density of stocking. Growth potential of the site is expressed in the amount of wood material laid down each year. As long as the site is fully occupied by trees of a height which the site will support, this amount will not greatly vary, whether the stand is overstocked or whether it is stocked with the optimum number of trees. However, the board foot growth and the quality of that growth will vary, depending upon stand structure and stocking. It will be shown later that basal area can be reduced most effectively by eliminating some of the very large trees that are seriously competing with high quality smaller trees, thus allowing the medium sized sawlog trees to make rapid growth during that period where growth is of most value.

The case history of a 9" white oak, aged 80 years, will serve as an interesting example of the effect of stand closure on growth. This tree was growing on a better than average oak-hickory site. The stand was roughly a two-aged forest which had been cut over in about 1895. The old holdovers were about 80 years old, and the younger trees 50 years old. From 1927 to 1947 this white oak tree made 0.8 inches diameter growth and had been gradually slowing down by five year periods. From 1907 to 1927, the previous 20 years, it grew 3.6" in diameter. This is $3\frac{1}{2}$ times the

diameter growth of the last 20 year period. The present growth as shown by the last 5 year period is at the rate of 0.4 inches in 20 years. This exemplifies what is happening to many of the overstocked stands, especially those on poorer sites. It is now apparent that all of the 20 plots examined are in need of a moderately heavy improvement and harvest cut. All inferior and defective trees would be taken, plus trees which are economically mature. The question of economic maturity will be discussed in the following sections under the headings of "Volume Maturity" and "Value Maturity".

Volume Maturity

The growth of one large tree as compared to the accelerated growth on smaller released trees is one key to a knowledge of volume economic maturity of trees from the standpoint of the whole stand. It is not sufficient to consider maturity of a single tree just as if it were growing in an open field. It must be considered in relationship to the rest of the stand, especially the competition it offers to smaller high quality trees. The evidence in tables 9 and 10 poses the question: How long can we afford to allow large trees to grow at the expense of smaller crop trees which would be released? This question could be approached directly by experimental plots and an answer obtained in 10 to 20 years. We need some indications before that time.

Considering volume only, table 11 shows the results of calculations attempting to answer the chief question in the above paragraph. The evidence is good that if cutting one large tree will release 2.5 to 3 11-13 inch trees, the growth on the smaller trees will balance the growth

Table 11.--Growth on large trees compared to growth on smaller trees for same period and to increased growth of released smaller trees

	Large trees		Smaller trees		Growth as unreleased intermediate trees. /2	Growth gain by release.	Released 11-13 inch trees needed to balance growth of large plus unreleased small
	Mean present d.b.h.	Actual yearly /1 growth	Mean present d.b.h.	Actual yearly /1 growth	11-13 d.b.h.	11-13 d.b.h.	
	Inches	Bd. ft.	Inches	Bd. ft.	Bd. ft.	Bd. ft.	No.
Example 1 White oak	26	7.8	17	6.0	3.0	3.0	2.6
Example 2 Black oak	23	7.8	17	6.0	3.0	3.0	2.6
Example 3 Yellow poplar	24/3	7.5	15	5.3	2.7	2.6	2.9

/1 Data from table 9. Growth for both large and smaller trees for same period; about 1913 to 1920. The smaller trees were growing from 11 d.b.h. to 13 inches d.b.h. Trees are dominant or co-dominant.
/2 Data from table 8. Intermediate crown class trees grew about one-half as much as dominant trees.

of the large tree plus the former growth of the smaller trees. If cutting a large tree will release more than that number, the large tree could not be economically left from the standpoint of volume growth as each of the smaller trees released will grow nearly as much as the large tree.

Table 11 (and table 9) shows that about 35 years ago, when the comparison of growth was made and the stands were less fully stocked, the smaller trees of 11-13 inches grew much more in proportion to their basal area than the larger trees. As the stands have closed in during the past 35 years, the growth on the larger trees, while decreasing, has held up better than growth on the smaller trees.

A striking comparison of board foot growth as related to basal area occupied can be given by considering the white oak example in table ~~11~~ 9. White oak, in growing from 11 to 13 inches d.b.h., grew an average of 6 bd. ft. per tree per year. During about the same period white oak, in growing from 20 to 22 inches, grew 7.8 bd. ft. per tree per year. But the basal area of the large white oak was 3.3 times that of the smaller one. Expressed another way the smaller trees grew 9.1 bd. ft. per year per square foot of basal area while the larger trees grew 3.6 bd. ft.

Later in this report a possible growth goal of 570 bd. ft. per acre per year is set up for the 80-90 foot site-type with a basal area of 91 square feet. If this basal area was occupied by 26 inch trees, there would be about 24 and each would have to grow 23.8 bd. ft. per year to give the 570 foot growth. In table 9 the largest growth of large white oaks was 7.8 and of large black oaks 7.85 bd. ft. This question will be discussed in further detail in the next section in connection with value maturity.

It seems apparent from the actual growth data that yearly board foot growth of larger trees is much smaller in proportion to basal area than for smaller trees. This is surely not a new idea and later it will be shown to hold on strictly mathematical grounds. In a given managed uneven-aged stand with a fairly constant and presumably optimum basal area, board foot growth would be greater if the basal area were occupied by smaller rather than larger trees. The actual tree economic maturity will have to be determined on a basis of value of the annual growth and interest earned on the investment. Obviously, this will also vary by site quality which effects both rate of growth and quality of products.

The European conflict between the "German" and "French" systems of intermediate cutting is sure to be encountered in the present study. The question could logically be asked, why not leave the large trees and cut the smaller ones to stimulate growth on the large? Cheyney [3] states that a cut of all suppressed, intermediates, and some of the smaller co-dominants is needed before stimulation of larger trees is obtained. The French system is based on the premise that suppressed and intermediate trees do not significantly effect the growth of the dominant crop trees. They make crown thinnings for growth stimulation purposes and this system is more commonly used in America. Without getting into a long discussion of this subject, it seems apparent that in an uneven-aged managed stand it would not be possible to cut large portions of the suppressed and intermediate crown classes and still maintain an uneven-aged forest.

The selection system of silviculture together with uneven-aged management depends upon an adequate distribution of size classes in the stand

[3] Cheyney, Edward G. 1942.
American Silvics and Silviculture.
Univ. of Minn. Press.

to take over openings created by improvement cuts and harvest cuts of mature trees. It seems plain that such harvest cuts will be taken from the larger trees but that large trees will not be left beyond the point where the same basal area would earn more if occupied by two or more smaller trees.

Value Maturity; Sawtimber

In uneven-aged stands annual value increase and interest earned will largely determine when trees should be cut to make way for the smaller crop trees. On the basis of board foot volume growth in relation to basal area occupied, trees of 20 inches make a poor showing in comparison with smaller trees.

Tables 12, 13 and 14 show the relation between the d.b.h. and the proportion of volume in different log grades (see Forest Products Laboratory log grades in Appendix). In mixed hardwood stands the proportion of Grade 1 logs increases with the size of the tree and Grade 3 logs decrease. For oak-hickory there does not appear to be any relationship between log grades and tree sizes. All grades are either Grade 2 or 3. Scarlet oak, as expected, was of poor quality.

In order to determine the value <u>per thousand board feet</u> for trees of different sizes, log grade proportions and log selling prices were combined. This relationship for oak is shown in figure 3 and for yellow poplar in figure 4. The value per thousand for oak remains about constant from 13 to 16" and then rises rather sharply to 19" and levels off from there on. Yellow poplar presents essentially the same picture. It seems apparent that from the standpoint of <u>value per thousand</u> of logs or stumpage, there

Table 12.--Log grade[1] volumes as related to diameter; all oaks, mixed hardwoods type

D.b.h. class	Proportion of bd. ft. volume[2]		
	Log grade 1	Log grade 2	Log grade 3
Inches	Percent of volume by diameter classes		
13-14	0	35	65
15	0	49	51
16	0	39	61
17	22	31	47
18	31	22	47
19	59	24	17
20	61	23	16
21	49	45	6
22	63	21	16
23-25	44	38	18
26+	69	0	31

[1] See Appendix for definition of log grades.

[2] Based on the ~~37~~ 40 oaks 13.6 inches d.b.h. and over on 10 one-tench acre plots.

Table 13.--Log grade volumes as related to diameter, yellow poplar, mixed hardwoods type

D.b.h. class	Proportion of bd. ft. volume /1		
	Log grade 1	Log grade 2	Log grade 3
Inches	Percent of volume by diameter classes		
13-14	9	48	43
15-16	19	47	34
17-19	47	33	20
20-22	42	51	7
23-26	64	0	36

/1 Based on the 11 yellow poplars 13.6 inches d.b.h. and over on 10 one-tenth acre plots.

Table 14.--Log grade volumes as related to diameter, all oaks, oak-hickory type

D.b.h. class	Proportion of bd. ft. volume/1		
	Log grade 1	Log grade 2	Log grade 3
Inches	Percent of volume by diameter classes		
14	0	36	64
15	0	35	65
16	0	38	62
17	0	59	41
All white and black oaks	0	37	63
All scarlet oaks	0	6	94

/1 Based on 16 white and black oaks and 7 scarlet oaks 13.6 inches d.b.h. and over on 10 one-tenth acre plots.

Relation Between Tree Diameter and Value of Logs Per M
All Oaks; Mixed Hardwoods Type

	Assumed Dollar Values Per M: Stumpage	Assumed Dollar Values Per M: Side of road
Log grade No. 1	21.00	39.00
Log grade No. 2	8.50	26.00
Log grade No. 3	0	14.00

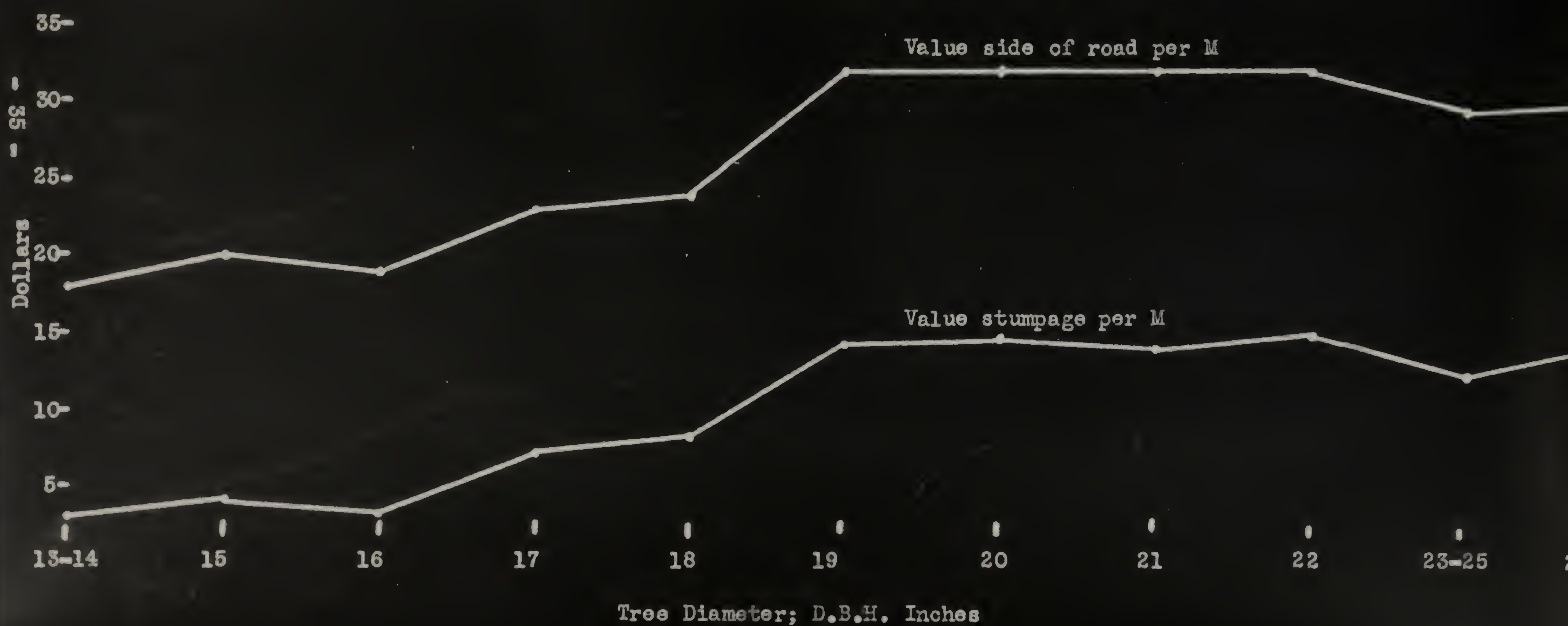

Figure 3

Relation Between Tree Diameter and Value of Logs per M
Yellow Poplar; Mixed Hardwoods Type

	Assumed Dollar Values per M	
	Stumpage	Side of road
Log grade No. 1	21.00	39.00
Log grade No. 2	8.50	26.00
Log grade No. 3	0	14.00

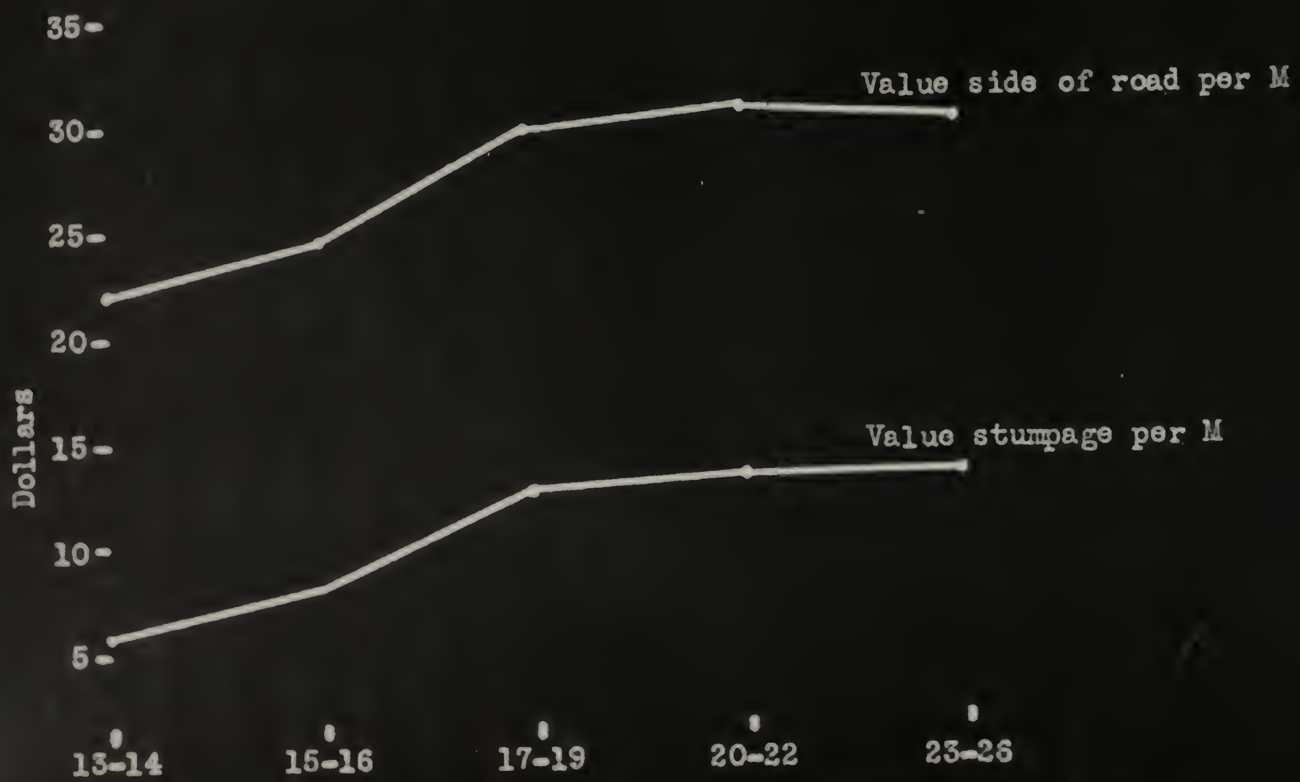

Figure 4

is no justification for growing trees larger than about 20". Before this can be accepted or rejected, however, further detailed discussion is necessary.

The log prices used in figures 2 and 3 are those stated in the cooperative agreement between the Sahara Coal Company and the Central States Forest Experiment Station. They are probably fair and equitable for present conditions in southern Illinois. Actually, few sales are made on a log grade basis and a woodland owner can usually do little better than sell woods' run logs, except those suitable for stave bolts or veneer. In spite of this, however, the log grades alone do not accurately reflect the lumber grade recovery and lumber value of <u>different sized logs in the same log grade</u>. Figures 2 and 3 probably give a fair picture of what the average woodland owner could realize, and in that case, the value maturity guides indicated would not be far wrong. The greatest value increase is from about 16 to 19 inches d.b.h. and levels off at about that point. It shows that cutting good trees of 15-16 inches is very poor business and that leaving them after 19-20 inches is probably also poor business.

The <u>intrinsic</u> value of the standing trees, as reflected in lumber grade recovery, is beyond the scope of this paper and probably more academic than practical. However, the actual value of the lumber recovered from trees of different sizes can be calculated based on work of the Forest Products Laboratory. Table 15 gives the dollar values of logs, stumpage, and actual lumber recovered. Reading of the two footnotes is essential to an understanding of how figures were calculated. Factors considered were log grades, logging costs, lumber grade recovery by log grades and

Table 15.--Dollar values of logs and lumber by tree diameter classes; white oak, black and red oaks, and yellow poplar

Tree d.b.h.	Value logs side of road per M /1	Assumed logging and skidding costs per M	Value stumpage per M/1	Lumber value per M based on /2 grade recovery: White oak	Black and red oaks	Yellow poplar
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
11-14	18.00	16.00	2.00	56.80	59.43	75.94
15-16	19.50	14.00	5.50	65.25	60.15	79.39
17	23.00	12.00	11.00	74.91	69.18	86.20
18	24.50	12.00	12.50	87.55	77.31	-
19	32.00	12.00	20.00	-	88.20	-
20	32.00	12.00	20.00	-	91.18	93.24
21-22	32.00	12.00	20.00	101.75	93.61	-
23-25	30.00	12.00	18.00	99.29	97.34	93.42
26-plus	30.00	12.00	18.00	120.62	100.34	104.74

/1 Based on Forest Products Laboratory log grades actually found on plots studied. Dollar values for logs at side of road were assumed to be those set up in cooperative agreement with Sahara Coal Company for oaks and yellow poplar as follows:

Log grade No. 1 - $39.00
Log grade No. 2 - 26.00
Log grade No. 3 - 14.00

/2 Based on actual Forest Products Laboratory log grades found on plots studied and on lumber grade recovery and lumber prices by log grades and log diameter given in "Hardwood Log Grades for Standard Lumber", No. D1737, Forest Products Laboratory, March 1949.

log size, and dollar prices for the graded lumber. The figures show plainly that total lumber value per M increases with tree size beyond the 19 inches indicated for stumpage value. Whether much of this extra value is returned to the private owner who sells logs is questionable. On a National Forest it would presumably be considered in the appraisal. A timberland owner who manufactured his own lumber would benefit from the full value of the graded lumber.

In order to attempt a solution to the value maturity of trees of different sizes in relation to their growth and basal area tables 16, 17, and 18 were constructed. Each is for a different site-type as indicated and each is based on the dollar values in table 15. Only three of the five site-types are represented. Figures 5 and 6 give the plotted values from the tables of the best and the poorest site-types.

The tables are based on the assumption that all trees from 11 to 30 inches have the same yearly diameter growth. This could only be achieved in carefully managed stands. Most actual stands would behave differently and growth rings often become narrower as trees approach 30 inches d.b.h. unless the site is excellent. The growth assumption therefore tends to favor the larger trees.

The three tables and the figures present significant and useful information. The slope of the lumber value and stumpage value curves are steepest from 16 to 19 inches d.b.h. and after about that point the steep rise of the basal area curve is steeper than the growth or value curves. Simple interest earned (yearly growth percent in tables 16, 17, 18) falls below 3 percent at 20 inches on the best site and falls below 2 percent at 21 inches on the medium and poor sites.

Table 16.--Growth, volume, and value of single trees on 90+ foot site by diameter classes and assuming constant growth of 1 inch in diameter every 4 years; black and red oaks [1]

D.b.h.	Merch. height	Volume	Growth	Yearly growth	Yearly growth	Lumber value of volume	Stumpage value of volume [2]	Stumpage value yearly growth	Lumber value yearly growth	Basal area
Inches	Logs	Bd. ft.	Bd. ft.	Bd. ft.	Percent	Dollars	Dollars	Dollars	Dollars	Sq. ft.
11	2	70	70	17.5	25.0	4.16	0.14	.035	1.03	.66
12	2½	98	28	7.0	7.14	5.82	0.20	.014	0.41	.79
13	2½	120	22	5.5	4.58	7.13	0.24	.011	0.32	.92
14	3	162	42	10.5	6.48	9.63	0.32	.021	0.62	1.07
15	3	194	32	8.0	4.12	11.67	1.07	.044	0.48	1.23
16	3	226	32	8.0	3.54	13.59	1.24	.044	0.48	1.40
17	3	262	36	9.0	3.44	18.13	2.88	.099	0.62	1.58
18	3	297	35	8.8	2.96	22.96	3.71	.110	0.68	1.77
19	3	337	40	10.0	2.97	29.72	6.74	.200	0.88	1.97
20	3	377	40	10.0	2.65	34.37	7.54	.200	0.91	2.15
21	3	422	45	11.2	2.65	39.50	8.44	.224	1.05	2.41
22	3	467	45	11.2	2.40	43.72	9.34	.224	1.05	2.64
23	3	517	50	12.5	2.42	50.32	10.34	.250	1.21	2.89
24	3	567	50	12.5	2.20	55.19	11.34	.250	1.21	3.14
25	3	626	59	14.7	2.35	60.93	12.52	.294	1.42	3.41
26	3	684	58	14.5	2.12	68.63	13.68	.290	1.45	3.69
27	3	745	61	15.3	2.05	74.75	14.90	.306	1.53	3.98
28	3	806	61	15.3	1.90	80.87	16.12	.306	1.53	4.28
29	3	870	64	16.0	1.84	87.30	17.40	.320	1.60	4.59
30	3	933	63	15.8	1.69	93.62	18.66	.316	1.58	4.91

[1] Used Mesavage volume tables, International gross scale and dollar values in table 15 based on log grades and lumber grade recovery. The assumed constant growth could be realized only in a properly managed stand.

[2] Stumpage values would be higher and about parallel to lumber values for the larger trees when stumpage is an accurate reflection of lumber values based on full grade recovery. Costs of logging, transportation, and milling are so variable that no attempt has been made to compute "just" stumpage values based on actual value of lumber recovered.

Table 17.--Growth, volume, and value of single trees on 70-80 foot site by diameter classes and assuming constant growth of 1 inch in diameter every 5 years; black and red oaks [1]

D.b.h.	Merch. height	Volume	Growth	Yearly growth	Yearly growth	Lumber value of volume	Stumpage value of [2] volume	Stumpage value yearly growth	Lumber value yearly growth	Basal area
Inches	Logs	Bd. ft.	Bd. ft.	Bd. ft.	Percent	Dollars	Dollars	Dollars	Dollars	Sq. ft.
11	1½	56	56	11.2	20.0	3.32	0.11	.022	0.65	.66
12	2	85	29	5.8	6.82	5.05	0.17	.011	0.34	.79
13	2	104	19	3.8	3.65	6.18	0.20	.008	0.22	.92
14	2½	143	39	7.8	5.45	8.50	0.29	.016	0.46	1.07
15	2½	170	27	5.4	3.18	10.23	0.94	.030	0.33	1.23
16	2½	198	28	5.6	2.83	11.91	1.09	.031	0.34	1.40
17	2½	228	30	6.0	2.63	15.77	2.51	.066	0.41	1.58
18	2½	259	31	6.2	2.39	20.02	3.24	.078	0.48	1.77
19	2½	294	35	7.0	2.38	25.93	5.88	.140	0.62	1.97
20	2½	328	34	6.8	2.07	29.91	6.56	.136	0.62	2.15
21	2½	367	39	7.8	2.13	34.35	7.34	.156	0.73	2.41
22	2½	406	39	7.8	1.92	38.00	8.12	.156	0.73	2.64
23	2½	448	42	8.4	1.88	43.61	8.06	.151	0.81	2.89
24	2½	491	43	8.6	1.75	47.79	8.84	.155	0.83	3.14
25	2½	542	51	10.2	1.88	52.76	9.76	.184	0.99	3.41
26	2½	592	50	10.0	1.69	59.40	10.66	.180	1.00	3.69
27	2½	644	52	10.4	1.61	64.61	11.59	.187	1.04	3.98
28	2½	696	52	10.4	1.49	69.84	12.53	.187	1.04	4.28
29	2½	750	54	10.8	1.44	75.25	13.50	.194	1.08	4.59
30	2½	805	55	11.0	1.37	80.77	14.49	.198	1.10	4.91

[1] Used Mesavage volume tables, International gross scale and dollar values in table 15 based on log grades and lumber grade recovery. The assumed constant growth could be realized only in a properly managed stand. It is doubtful whether trees could maintain this growth up to 30 inches on any except the best sites, even if properly managed.

[2] Stumpage values would be higher and about parallel to lumber values for the larger trees when stumpage is an accurate reflection of lumber values based on full grade recovery. Costs of logging, transportation, and milling are so variable that no attempt has been made to compute "just" stumpage values based on actual value of lumber recovered.

Table 18.--Growth, volume, and value of single trees on 60- foot site by diameter classes and assuming constant growth of 1 inch in diameter every 5 years; black and red oaks /1

D.b.h.	Merch. height	Volume	Growth	Yearly growth	Yearly growth	Lumber value of volume	Stumpage value of /2 volume	Stumpage value yearly growth	Lumber value yearly growth	Basal area
Inches	Logs	Bd. ft.	Bd. ft.	Bd. ft.	Percent	Dollars	Dollars	Dollars	Dollars	Sq. ft.
11	1	43	43	8.6	20.0	2.55	0.09	.017	0.51	.66
12	1½	68	25	5.0	7.35	4.04	0.14	.010	0.30	.79
13	1½	84	16	3.2	3.81	4.99	0.17	.006	0.19	.92
14	1½	99	15	3.0	3.03	5.88	0.20	.006	0.18	1.07
15	1½	116	17	3.4	2.93	6.98	0.64	.019	0.20	1.23
16	1½	134	18	3.6	2.69	8.06	0.74	.020	0.22	1.40
17	1½	154	20	4.0	2.60	10.65	1.69	.044	0.28	1.58
18	1½	175	21	4.2	2.40	13.52	2.19	.053	0.32	1.77
19	1½	198	23	4.6	2.32	17.46	3.96	.092	0.41	1.97
20	1½	220	22	4.4	2.00	20.05	4.40	.088	0.40	2.15
21	1½	246	26	5.2	2.11	23.03	4.92	.104	0.49	2.41
22	1½	271	25	5.0	1.85	25.37	5.42	.100	0.47	2.64

/1 Used Mesavage volume tables, International gross scale and dollar values in table 15 based on log grades and lumber grade recovery. The assumed constant growth could be realized only in a properly managed stand.

/2 Stumpage values would be higher and about parallel to lumber values for the larger trees when stumpage is an accurate reflection of lumber values based on full grade recovery. Costs of logging, transportation, and milling are so variable that no attempt has been made to compute "just" stumpage values based on actual value of lumber recovered.

Annual Growth Per Tree; 90+ Foot Site; Black and Red Oaks

Data From Table 16

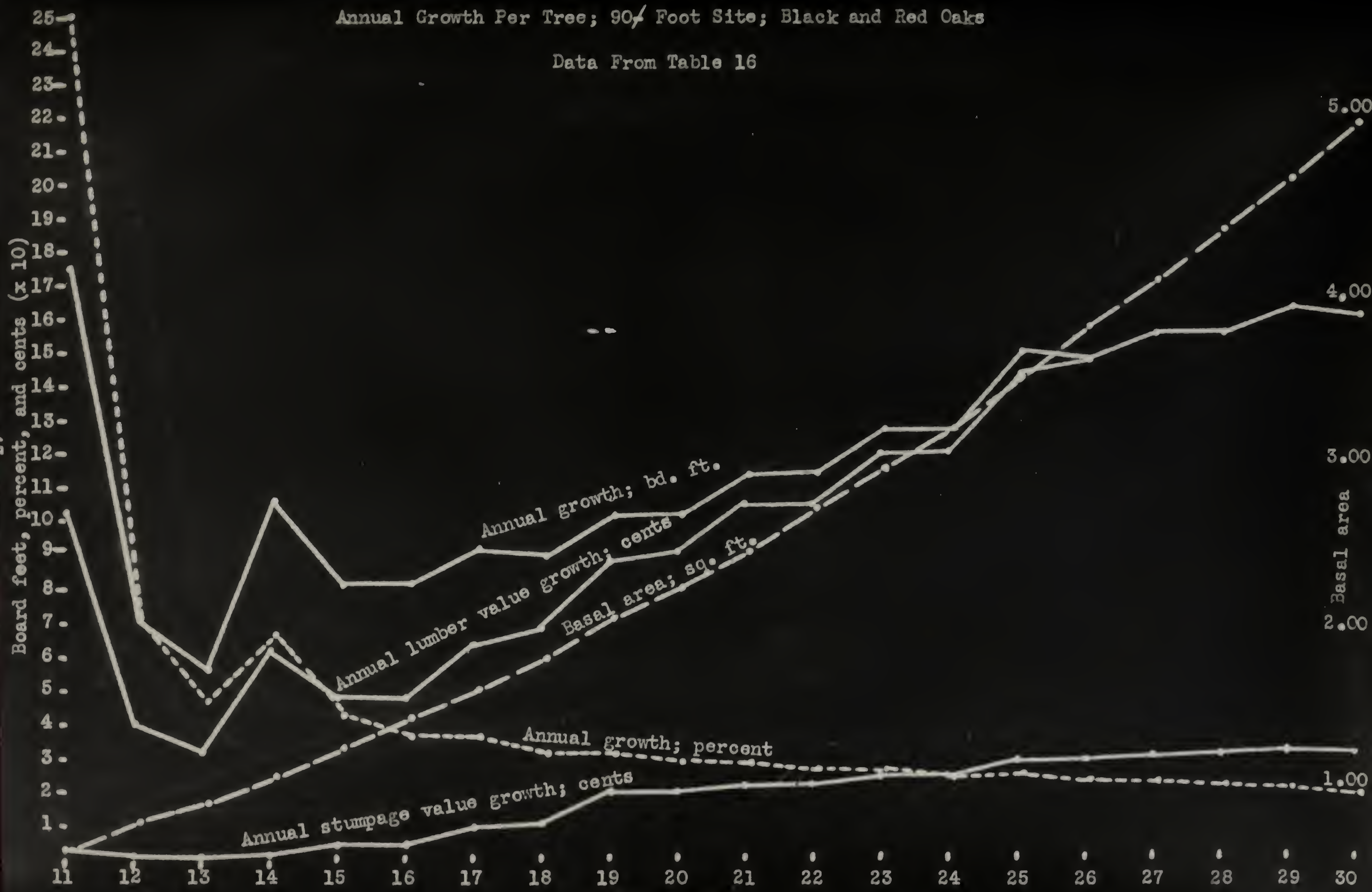

Figure 5

Annual Growth Per Tree; 60- Foot Site; Black and Red Oaks

Data From Table 18

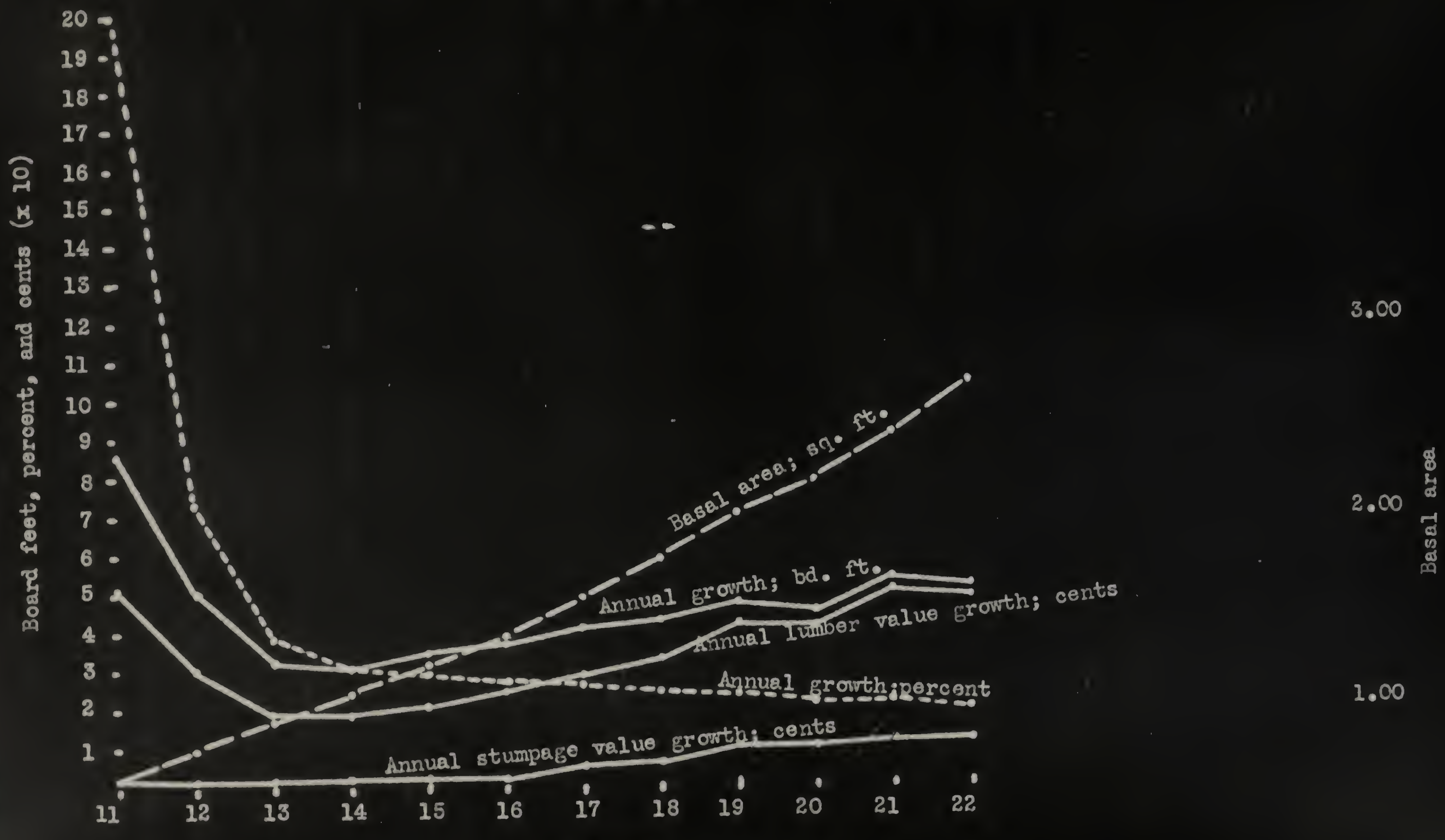

Figure 6

Comparing 19 and 30 inch trees on the best site yearly board foot growth per tree is about 1.6 times greater on the larger tree, but basal area is 2.5 times greater. It is interesting to note that this is almost the exact relationship between the perimeter and the area of a circle. If you substitute 19 and 30 in the appropriate formula, the ratio of perimeters of the two circles is 2.5 and the ratio of areas is 1.6, the same as noted above for growth and basal area. This is logical, but it came as a new idea to the writer.

It is apparent that basal area increases much faster than growth as a tree grows in size. Another way of showing this is to set up a growth goal of 650 bd. ft. Growing at the same rate, it would require 41 30-inch trees or 65 19-inch trees to make that growth. The point is that the 41 30-inch trees would occupy 201 sq. ft. basal area and the 65 19-inch trees only 128 sq. ft.

Table 19 shows a more detailed comparison of 19 and 30 inch trees. With the footnotes it is self-explanatory. Diameter growth is the same for both sizes and the stand must be an uneven-aged forest with a fairly constant and optimum basal area where replacements are available for trees cut. For 19 inch trees the current interest earned is 3 percent and for 30 inch trees it is 1.7 percent. In terms of value of yearly growth the smaller trees are superior whether lumber or stumpage value is used.

The question of interest earned by growing trees has received some attention but probably not as much as it deserves. If a tree is worth 20 dollars on the stump and is increasing in value at the rate of 30 cents a year, the tree is earning only 1.5 percent interest on the investment. There is a very real question whether an owner can afford to allow such

Table 19.--Comparison of value and basal area of 19 inch and 30 inch black or red oak in uneven-aged stand on 90/ foot site [1]

Factor evaluated	19 inch tree	30 inch tree
Trees to occupy 4.9 sq. ft. basal area; number [2]	2.5	1.0
Yearly growth of trees; bd. ft.	25.0	15.8
Yearly growth stumpage value; dollars	0.50	0.32
Yearly growth lumber value; dollars	2.20	1.58
Whole volume value; stumpage; dollars	16.85 (80 yrs.)	18.66 (124 yrs.)
Whole volume value; lumber; dollars	74.15 (80 yrs.)	93.30 (124 yrs.)
Stumpage value income per year; dollars	0.21	0.15
Lumber value income per year; dollars	0.93	0.75
Current interest earned; percent	3.0	1.7

[1] Values taken from table 16. Growth of both tree sizes assumed as 1 inch diameter in 4 years.
[2] Must assume uneven-aged managed stand where replacements are constantly available for trees cut.

a tree to go uncut (This interest earned would be the same, of course, whether it was based on stumpage value or lumber value). He cannot allow it to stand if other smaller trees will earn 3 or 4 percent interest on their value. In a well managed stand there will always be replacements to use the space vacated by cut trees. If replacements are not available, it is up to the owner to determine whether he can do better than 1.5 percent in some other investment. If replacements are available, the evidence seems clear that the low interest tree certainly should not be left. Some foresters seem to miss this point[4]. If the stand is properly managed and stocked, cutting the low interest trees will not put the owner out of the forestry business. He will be placing the growth potential of the site on trees that do pay higher interest.

Heiberg[5] has stressed the concept of economic increment and constructed a chart of economic cutting based on the interest earned by the tree investment. Tables 16, 17, and 18 show the simple interest earned on three site-types, assuming a constant diameter growth rate for all sized trees.

The Southeastern Forest Experiment Station, in their Biennial Report, 1947 and 1948, Station Paper No. 2, page 18, state as follows: "We know that only northern red oak and yellow poplar can be expected to return three percent or more of compound interest if held until 24 inches d.b.h. Sweet birch and sugar maple will not justify holding beyond 20 inches d.b.h. The other hardwoods studied reach economic maturity at 22 inches d.b.h."

/4 Stevenson, Donald D. 1942. Economics and silviculture. Jour. Forestry 40: 899-900.

/5 Heiberg, S. O. 1942. Cutting based upon economic increment. Jour. Forestry 40: 645-651.
Heiberg, S. O. 1942. Economics and silviculture. Jour. Forestry 40: 900-901.

Zillgitt[6] found that a residual volume of 3500 board feet per acre at a 15 year cutting cycle earned the highest interest, 3.6 percent compound. This stocking was too light for maximum growth and he concluded that about 5.5M bd. ft. (60 sq. ft. at basal area) would provide good growth plus a satisfactory return on the investment. In an uneven-aged forest not many trees over 20" d.b.h. could be included in such a stand.

Table 20 is copied from a Region 9 Forest Service publication[7] and shows the leveling off of value increase per year for the larger tree diameters of yellow birch and basswood. Sugar maple continues to increase to 32". Between 20" and 32" the yellow birch yearly value change increases only 1.1 times while basal area increases 2.6 times. Yearly value increases expressed as percentages come down steadily from 18 to 32 inches d.b.h. for all species.

All of the evidence presented tends to confirm the conclusion that in uneven-aged stands where replacements are available for sawtimber trees removed, 20 to 22 inches d.b.h. represents economic maturity for desirable species on good sites. This would be lower for poor species like hickory and black gum and would be progressively lower for poorer site-types. On the sole basis of interest earned trees over about 20 inches will not earn three percent per year.

Value Maturity; Furniture Veneer Trees

In the present study furniture veneer trees were not recognized or tallied and it is very doubtful if any of the trees on the study plots

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[6] Optimum economic stocking for northern hardwoods. 1948. Station Paper No. 10. Lake States Forest Experiment Station.

[7] Reference given bottom of table 20.

Table 20.--Annual increase in marginal value per tree; commercial trees suitable for cutting; all tree classes combined [1]

D.b.h.	Sugar maple		Yellow birch		Basswood		Basal area
	Percent	Dollars	Percent	Dollars	Percent	Dollars	Sq. ft.
14	-	.040	-	.074	-	.086	1.07
16	-	.062	10.8	.092	15.2	.114	1.40
18	8.6	.069	4.3	.094	6.1	.126	1.77
20	4.7	.080	2.9	.106	3.9	.138	2.18
22	3.9	.108	2.2	.116	2.6	.135	2.64
24	3.6	.151	1.8	.127	2.1	.142	3.14
26	3.2	.199	1.4	.128	1.8	.149	3.69
28	2.5	.229	1.2	.129	1.6	.159	4.28
30	2.5	.303	0.9	.124	1.5	.181	4.91
32	1.9	.320	0.8	.119	1.3	.187	5.59

[1] Copied from pages 42, 43, and 44 of "Comparison of Investment and Earnings of Hardwood Trees in the Northern Lake States". Region 9, U. S. Forest Service, Milwaukee, Wisconsin.

were of veneer quality. Some discussion and appraisal of veneer trees, however, is necessary to present as accurate a picture as possible.

The basic information on prices and specifications for veneer trees was obtained from Mr. Paul Johnson, forester and log buyer for the Curry Miller Veneer Company, Inc. of Indianapolis. Veneer operators need soft textured, slow growing trees with preferably about 20 rings to the inch. Most veneer trees purchased are 200-400 years old. No tree with large dead limbs, stag head, lightning scars, swollen butt, frost cracks, or swollen branch stubs are accepted. The logs purchased are from 6 to 12 feet in length and without defect except for small sound knots lined up in one plane along the log. In the great majority of cases only the butt log is used for veneer.

Maximum prices are paid for white oak logs 23 inches i.b. and over and for red oak and yellow poplar 20 inches i.b. and over. This means, in effect, that white oak trees 26-28 inches d.b.h. have about reached their maximum value per M for veneer logs. For yellow poplar and red oak this size would be about 24 inches. In view of this and the past discussion of growth and basal area nothing would be gained by growing veneer trees in uneven-aged managed stands over 26-28 inches d.b.h. The question is, will it pay to grow them to that point, in view of the premium prices received. If other companies pay maximum prices for logs larger than 23" i.b., then the value maturity of veneer trees would be correspondingly larger.

The following examples are given to illustrate and help show the problem:

Example 1: A 26" 3 log white oak with a 12 foot veneer butt log.

12' veneer log--285 bd. ft. at $115 per M	=	$32.77	stumpage
Sawtimber--400 bd. ft. at $20 per M	=	8.00	"
Total	=	$40.77	stumpage
Tree all sawtimber--685 bd. ft. at $20 per M	=	13.68	"
Weighted value combined products; per M	=	59.52	"
Tree all sawtimber; lumber value per M	=	82.00	lumber

Example 2: A 24" 3 log red oak with a 12 foot veneer butt log.

12' veneer log--210 bd. ft. at $35 per M	=	$ 7.35	stumpage
Sawtimber--357 bd. ft. at $20 per M	=	7.14	"
Total	=	$14.49	stumpage
Tree all sawtimber--567 bd. ft. at $20 per M	=	11.34	"
Weighted value combined products per M	=	25.55	"
Tree all sawtimber; lumber value per M	=	55.00	lumber

Example 3: A 24" 3 log yellow poplar with a 12 foot veneer butt log.

12' veneer log--210 bd. ft. at $60 per M	=	$12.60	stumpage
Sawtimber--357 bd. ft. at $20 per M	=	7.14	"
Total	=	$19.74	stumpage
Tree all sawtimber--567 bd. ft. at $20 per M	=	11.34	"
Weighted value combined products per M	=	34.81	"
Tree all sawtimber; lumber value per M	=	52.73	lumber

There is little doubt that the extra prices received for veneer logs dictate that veneer trees should be sold for that purpose rather than sawtimber alone. Some idea of the relative earning power of a veneer tree can be gained from the following illustration:

A 26 inch high quality veneer white oak would be about 240 years old. This is at the rate of 20 rings to the inch with allowance for more rapid growth during pole stages. Its volume would be 685 bd. ft. and its total value, as just calculated, would be $40.77 or $59.52 per M. Its present growth as a 26 inch tree would be 5.8 bd. ft. per year. At $59.52 per M this would be a value growth of $.345 stumpage per year. A 26 inch sawtimber tree growing 14.5 bd. ft. per year (table 16) at $20 per M would earn $.290 yearly in stumpage. The interest earned by the veneer tree would be

.345/40.77 or 0.85%. Interest earned by the sawtimber tree (table 16) would be 2.1%. It seems apparent again that veneer trees should not be left to grow over 26-28 inches, the point where maximum price per M is reached.

During its lifetime the 26" veneer tree would earn an average of $0.17 per year (40.77/240). The 26" sawtimber tree would earn $0.13 per year (13.68/104). However, on the basis of compound interest on costs and investment the 240 year period would show extremely low returns. The simple interest earned per year is only 0.85 percent and becoming smaller every decade.

Stand basal area for veneer log forestry could be considerably higher than for sawlog forestry. With 20 rings to the inch as a growth goal, basal areas might be raised to around 180 sq. ft. on good sites suitable for veneer trees. With 8 rings to the inch growth for sawtimber basal area would probably have to be held to 110 on the same site quality. On a per acre basis, assuming trees even-aged and all 26" in diameter, the approximately 50 veneer trees would grow in value about $17 each year and the 30 sawtimber trees about $9. This, of course, is academic and probably useless speculation as stands don't grow that way. Perhaps the only conclusions we can draw from all this discussion on veneer trees are: (1) white oak should not be left beyond 26-28" and yellow poplar and red oak beyond 24" for veneer; (2) existing 20-22 inch sound healthy trees of veneer quality on good sites should be left to grow to veneer size if growth need not be slower than 15-20 rings per inch and especially if more rapid growth is acceptable; and (3) growing veneer trees from poles at 20 or even 15 rings to the inch will return a very low rate of interest on the investment.

Stand Structure; Well-Stocked Unmanaged Stands

The actual structure of the fully-stocked unmanaged stands examined is shown in tables 21 and 22 and in figures 7 and 8. These tables are expressed in both the number of trees per acre and in basal area per acre. Table 21 shows the number of trees per acre by diameter classes for the five site-types which have been recognized in this study. The most striking thing about the data in table 21 is that the better sites show a far greater number of large trees. The oak-hickory type has no trees over 17". Number of trees per acre and diameter distribution for the mixed hardwood type varies according to site-types. The uneven diameter distribution is a feature of these unmanaged stands.

Table 22 and figure 7 show the structure of the composite stand for oak-hickory and mixed hardwoods. Figure 7 again shows the uneven diameter distribution for both types and the abundant number of large trees in the mixed hardwood type. The basal area of the unmanaged composite stands shown in figure 8 emphasizes even more the uneven diameter distribution and the heavy proportion of basal area in trees of 26" and over for mixed hardwoods.

What then are the characteristics of unmanaged fully-stocked stands as shown in the preceding tables and figures? They have characteristics which are not desirable in a managed stand. These are listed as follows:

1. The diameter distribution is uneven. There are too few replacements in some diameter classes and too many in others.
2. Too much space is occupied by the large holdover trees in the mixed hardwood type.

Table 21.--Diameter distribution of well-stocked unmanaged stands

by site classes and types

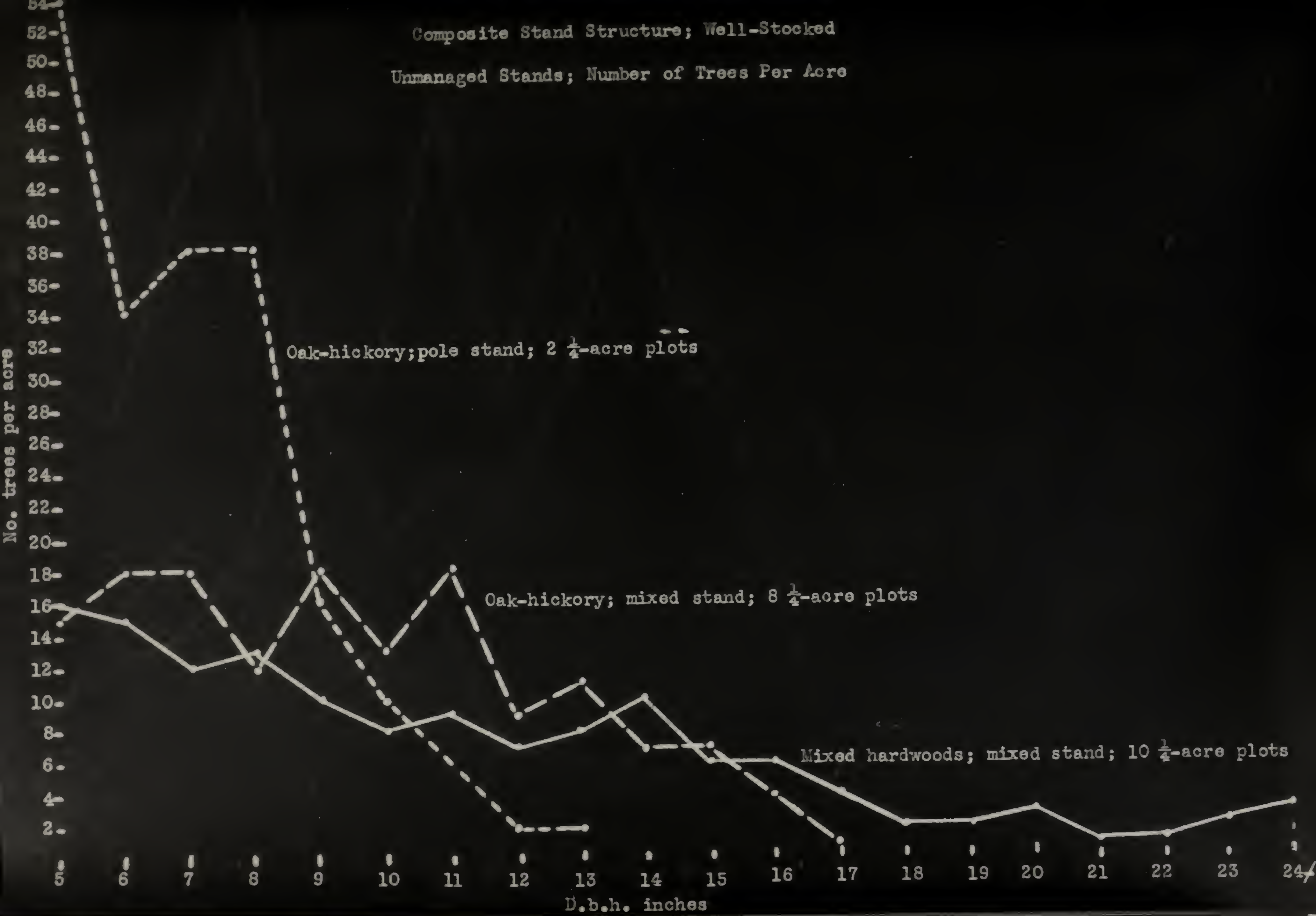
Site classes	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	Total trees
	D.b.h. inches — Number of trees per acre																														
Oak-hickory type. Height dominants less 65 ft. 3 ¼-acre plots	8	13	13	8	21	9	19	13	7	9	4	4	1																		129
Oak-hickory type. Height dominants over 65 ft. 5 ¼-acre plots	18	21	20	14	15	14	17	6	13	6	9	3	1																		157
Mixed hardwoods type. Height dominants 70-80 ft. 5 ¼-acre plots	14	16	17	9	10	7	13	11	7	11	6	4	6	3	1	2	0	1	1	0	1										140
Mixed hardwoods type. Height dominants 81-89 ft. 2 ¼-acre plots	18	22	8	24	6	6	2	8	6	10	10	4	4	0	0	2	4	2	0	0	0	4									140
Mixed hardwoods type. Height dominants 90 ft. 3 ¼-acre plots	19	8	8	12	13	11	8	0	9	8	1	9	0	1	4	5	0	1	4	0	3	0	0	1	0	1	0	0	0	1	127

Table 22.--Composite stand structure well-stocked unmanaged stands; acre basis

D.b.h. class	O.H. pole stand 2 ¼-acre plots		O.H. mixed stand 8 ¼-acre plots		M.H. mixed stand 10 ¼-acre plots	
	No. trees	Basal area	No. trees	Basal area	No. trees	Basal area
Inches		Sq. ft.		Sq. ft.		Sq. ft.
5	54	7.4	15	2.1	16	2.2
6	34	6.7	18	3.5	15	2.9
7	38	10.2	18	4.8	12	3.2
8	38	13.3	12	4.2	13	4.5
9	16	7.1	18	8.0	10	4.4
10	10	5.5	13	7.1	8	4.4
11	6	4.0	18	11.9	9	5.9
12	2	1.6	9	7.1	7	5.5
13	2	1.8	11	10.1	8	7.4
14			7	7.5	10	10.7
15			7	8.6	6	7.4
16			4	5.6	6	8.4
17			1	1.6	4	6.3
18					2	3.5
19					2	3.9
20					3	6.6
21					1	2.4
22					1	2.6
23					2	5.8
24					0	0
25					1	3.4
26					2	10.0

Composite Stand Structure; Well-Stocked

Unmanaged Stands; Number of Trees Per Acre



Composite Stand Structure; Well-Stocked

Unmanaged Stands; Basal Area Per Acre

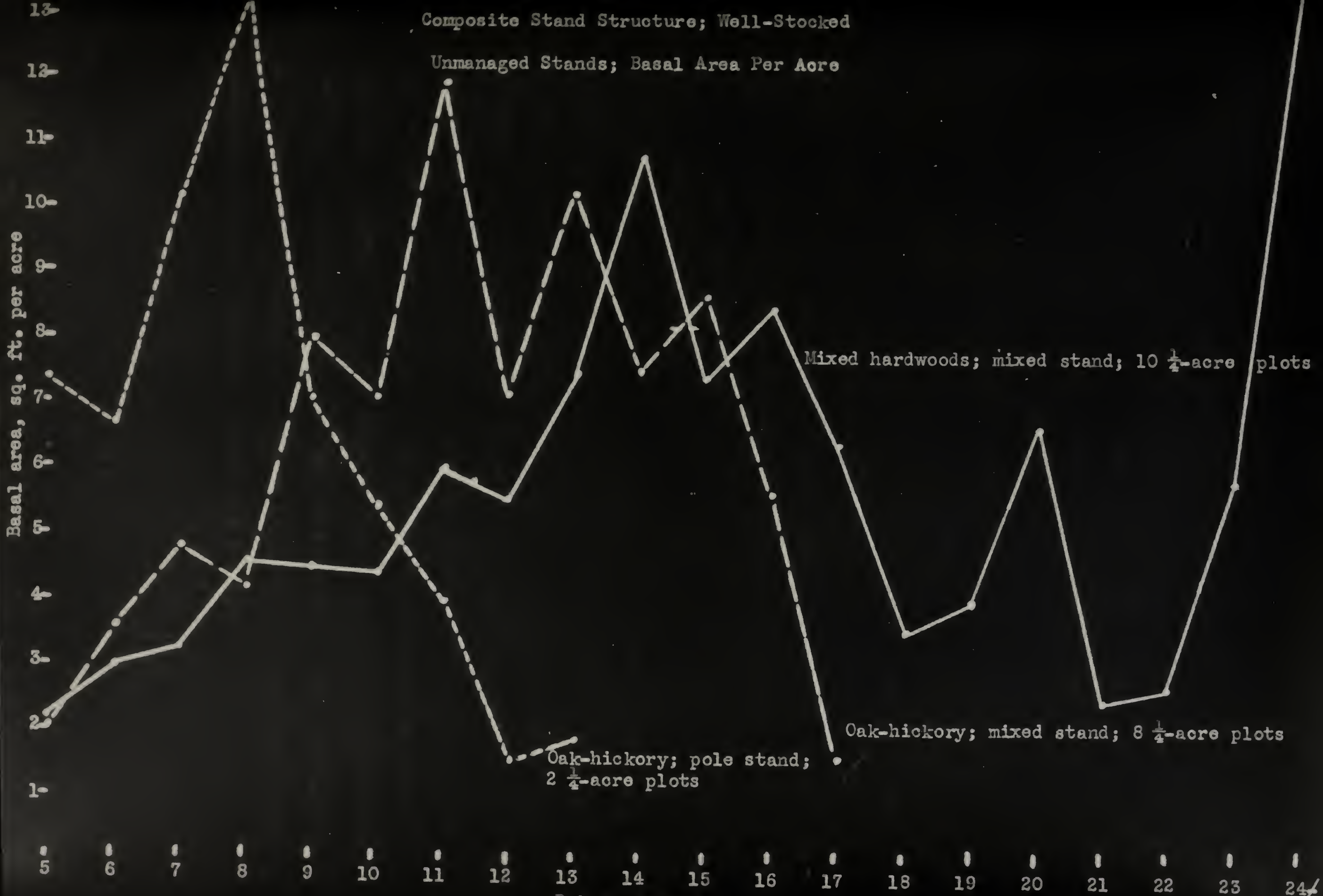


Figure 8

3. The stands probably have too high a basal area to take full advantage of the growing capacity of the site, i.e., place good growth on the best trees. Some of the stands are going backward and suffering mortality loss and some had a negative growth.
4. Too much of the growing capacity of the site is wasted on short boled, poorly formed and poor risk trees.
5. The wood is of rather low density and quality because of the progressively narrower growth rings.
6. The species composition could be improved by further elimination of such species as hickory, black gum and hard maple, but in general species composition is more satisfactory than diameter distribution, basal area and stocking.

With the foregoing data and conclusions at hand, it is desirable and logical that an attempt be made to set up an "ideal" stand. This would be a hypothetical stand. A real ideal stand could be realized only by management over many years. The following section is devoted to a description of stand structure for such an optimum stand. It is realized that this is based on some assumptions which would be impossible to prove at this time. Judgment of correct diameter distribution is especially weak. However, it is consistent with the data here presented, and I believe it is a reasonable and desirable management goal until we have more adequate information obtained from actual management practice.

STAND STRUCTURE; "IDEAL" MANAGED STANDS

The term "ideal" stand is used to designate that stand which, on the basis of the present evidence, seems to fulfill the requirements of an uneven-aged stand with optimum stocking. It is one of several that might be set up, but it seems approximately harmonious with the evidence on basal area, volume, diameter distribution, species composition, and economic maturity by site-types.

The species composition of an "ideal" managed stand should consist of the best and most valuable species which are ecologically suited to the particular site-type. The diameter distribution should be fairly even and with a continual reserve of small trees in lower diameter classes which will allow for necessary improvement cutting and insure a continual production of harvest type trees at maturity. In a stand with optimum stocking the number of trees, basal area, and volume should be just right to insure that the full growth potential of the site is placed on the best trees. Such a stand would be fully-stocked but by the correct tree sizes and diameter distribution, so as to take full advantage of the growth characteristics of the stand and the economic maturity of individual trees. The aim would be to place the growth potential of the site on trees of the best species, form, and bole length. This growth would also be high quality because of the uniformly fast growth rate.

The data on the unmanaged stands has shown conclusively that "ideal" stand structure must vary by site. Five site breakdowns have been set up in this study. Actually there are many more, and in practice others may be found. However, for practical purposes it is suggested that these five are about as wide a range as forest managers could handle at the present

time in the central hardwood region. It is also recognized that these sites will be different in different regions. The five here defined apply fairly well to the uplands of southern Illinois.

Figure 9 gives the form of the "ideal" stocking curve by the five sites which have been defined. It is apparent that the growth rate determines the slope of the individual diameter distribution curves. Growth rate varies by site because both diameter growth and merchantable height is greater on better sites. It has already been shown that on good sites trees over about 20-22" d.b.h. may not increase in stumpage value per thousand and also that in uneven-aged well-stocked stands their removal will usually result in an increased growth and value for the whole stand. However, this top limit of diameter will vary by sites and this corresponds to the form of diameter distribution curves as shown in figure 9.

Table 23 gives the assumed "ideal" basal area which will be used as a goal for a well managed stand. This varies by the five site-types. This assumed value is a reasonable assumption based on indications from the present data. It also matches, as it must, the "ideal" stand structure shown in figure 10 and figure 11. These "ideal" stands are based on the concept of tree volume and value maturity, as already discussed, and on the necessity for a rather even diameter distribution so that replacements will be provided all along the line in an uneven-aged stand. Figure 11 shows high basal areas in those diameters where value is increasing at the greatest rate, that is, from about 11 to 18" on the better sites. The assumed "ideal" basal areas correspond well with the actual basal areas in their relationship to site quality. The "ideal" basal area for the poorer sites has been reduced from the actual more than for the better sites.

Form of Proposed "Ideal" Diameter Distribution Curves by Type-Sites

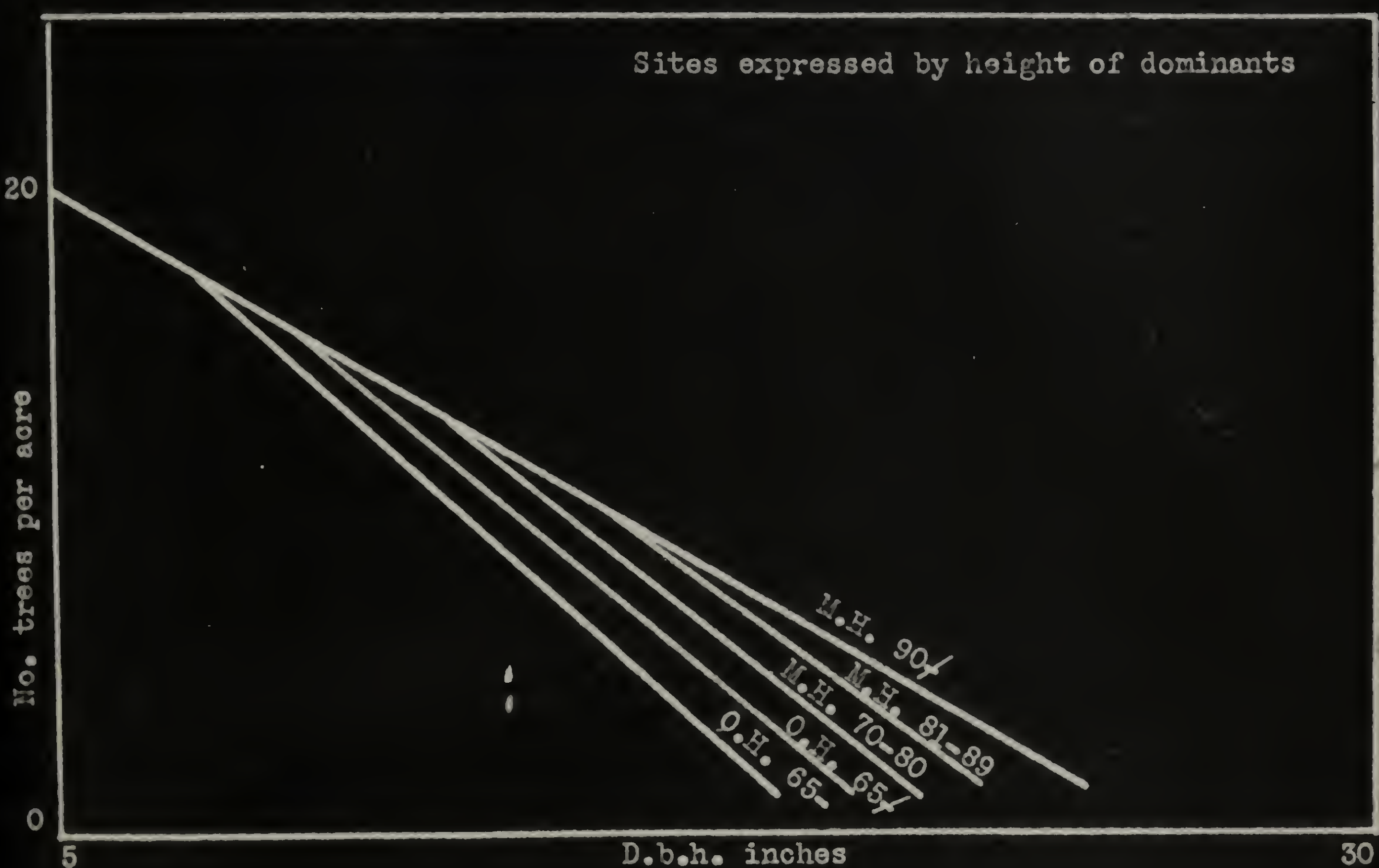


Figure 9

Table 23.--Assumed "ideal" basal area /1 by site-types; uneven-aged stands

Type	Site. Height dominant trees	Actual basal area per acre /1	Assumed /2 "ideal" basal area per acre	Calculated basal area of model stand. Table 24
	Feet	Sq. ft.	Sq. ft.	Sq. ft.
O.H.	Under 65	77	55	56
O.H.	Over 65	82	65	66
M.H.	70-80	97	80	80
M.H.	81-89	103	90	91
M.H.	90+	129	100	103

/1 Trees 4.6 inches d.b.h. and over.
/2 See discussion in text.

Actual "Ideal" Diameter Distribution Curves of Uneven-aged Stands by Type-Sites

Taken from Table 24

Sites Expressed by Height of Dominant Trees

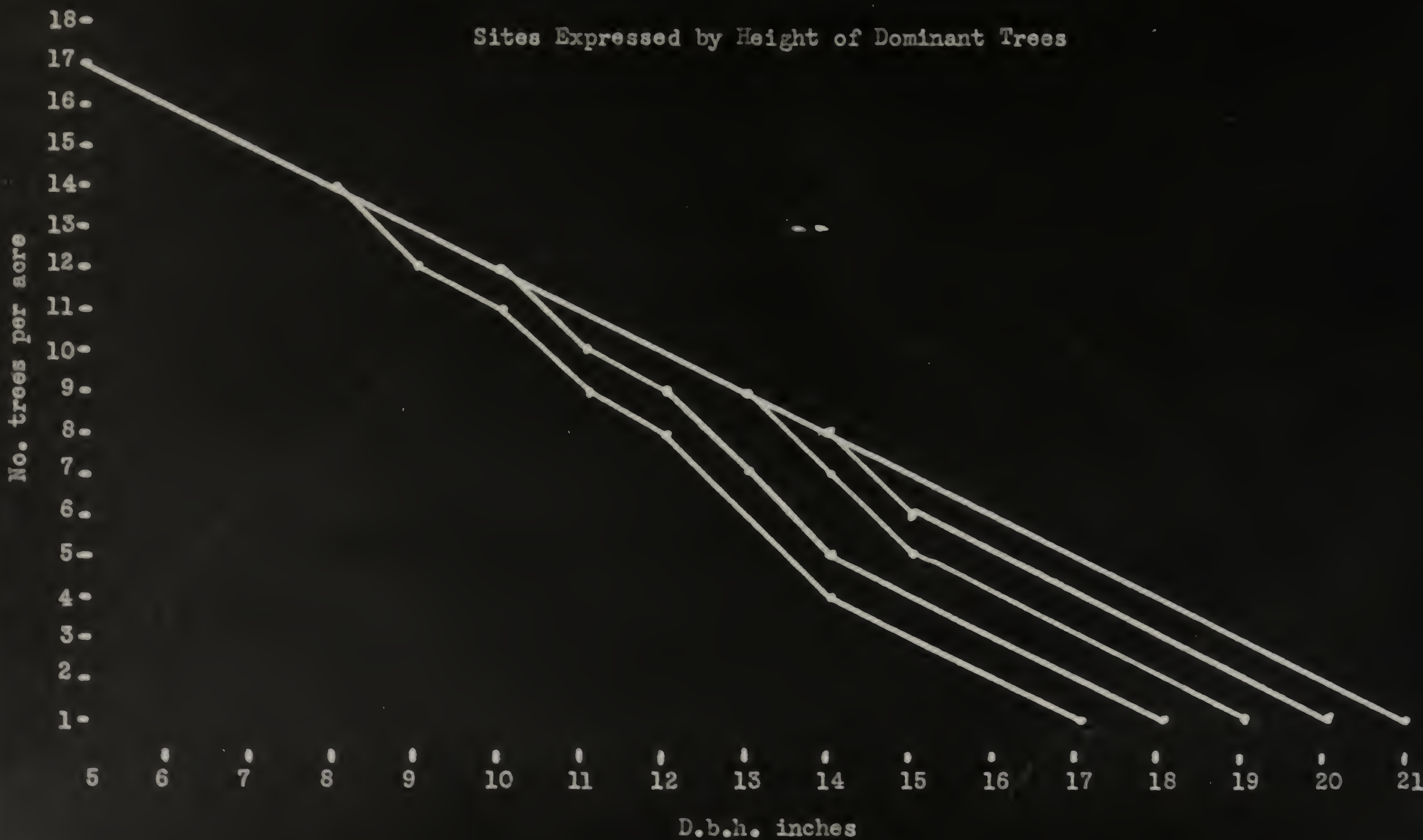


Figure 10

"Ideal" Basal Area Curves of Uneven-aged Stands by Site-Types

Taken from Table 24

Sites Expressed by Height of Dominant Trees

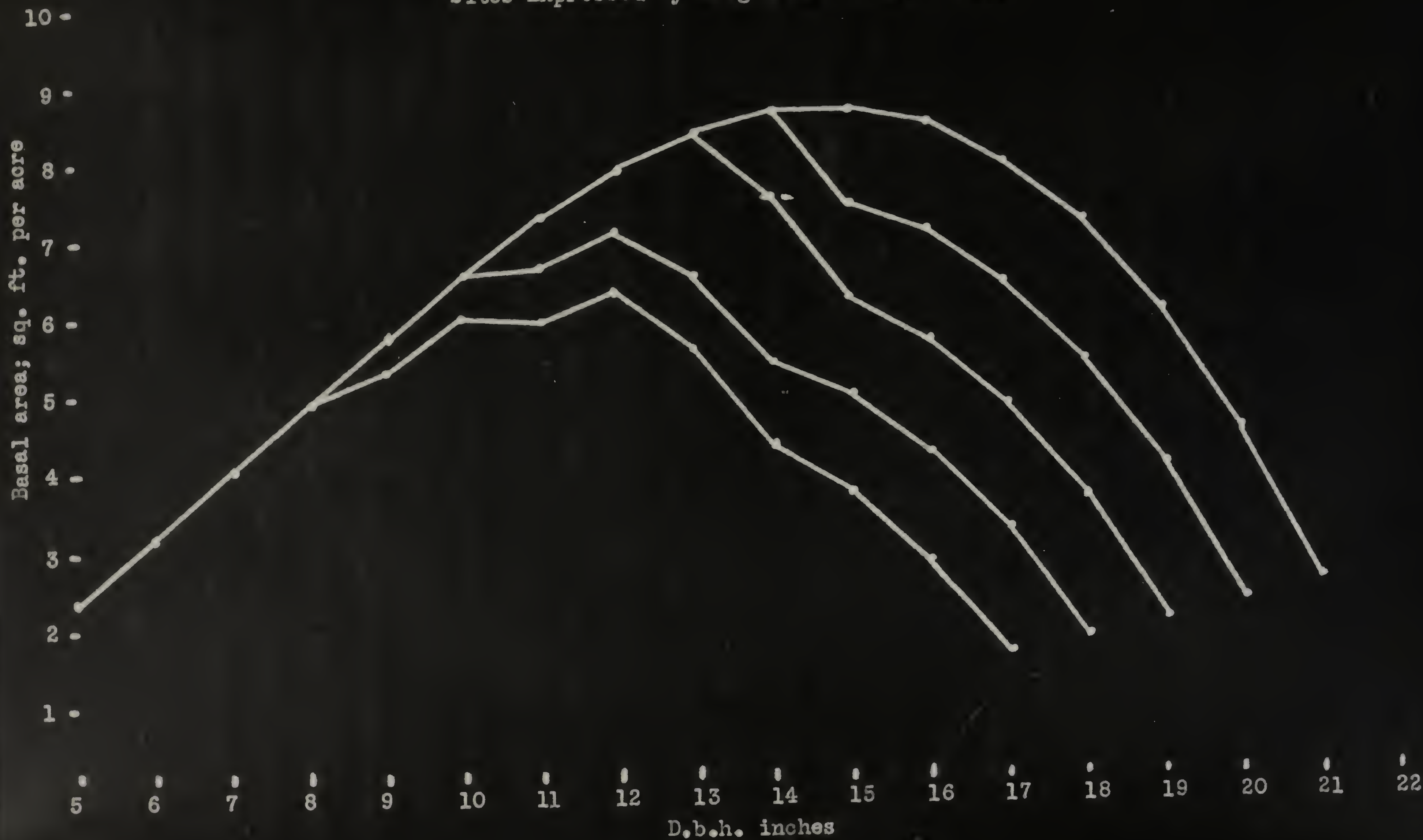


Figure 11

There were indications in the data that the poorer sites were relatively more heavily stocked than the better sites. There is no doubt that this approach to "ideal" stand structure by separation of sites is a sound one. It allows representation of the timber carrying capacity or growth potential of the sites. The calculated growth, volume and basal area will vary greatly, just as it did for the actual unmanaged stands.

The complete structure of the composite "ideal" stand by site-types is shown in table 24. A part of the basis for the calculations in this table are given in table 25. Table 24 gives the basal area and number of trees per acre by diameter classes for each of the five site-types. It shows the total number of trees per acre and the total basal area per acre. It gives the mean "ideal" merchantable height which might be expected from well managed stands. Those merchantable heights are in line with those already obtained and represent what might be expected if the poorer individuals were removed and the better individuals encouraged. The "ideal" volumes by site-types were actually calculated from the stand tables and merchantable heights as given in table 24. The mean "ideal" growth was calculated from the same table, making the reasonable growth assumptions shown in table 26.

Note from table 24 that volume increases from 2600 bd. ft. per acre on the poorest site to over 11,000 on the very best site, growth increases from 150 bd. ft. per acre per year to 640. Except for the poorest oak-hickory site, these "ideal" growths are all considerably greater than actual growth which is given in table 5. The chief point, however, is that in an "ideal" or managed stand growth would be placed on the best individuals, and all would be usable high quality growth.

Table 24.--Composite "ideal" stand structure by site-types;

per acre basis

D.b.h.	Forest type and height of dominants									
	O.H. under 65		O.H. 65-75		M.H. 70-80		M.H. 81-89		M.H. 90+	
	Trees	Basal area	Trees	Basal area	Trees	Basal area	Trees	Basal area	Trees	Basal area
Inches	Number	Sq. ft.	Number	Sq. ft.	Number	Sq. ft.	Number	Sq. ft.	Number	Sq. ft.
5	17	2.3	17	2.3	17	2.3	17	2.3	17	2.3
6	16	3.1	16	3.1	16	3.1	16	3.1	16	3.1
7	15	4.0	16	4.0	15	4.0	15	4.0	15	4.0
8	14	4.9	14	4.9	14	4.9	14	4.9	14	4.9
9	12	5.3	13	5.7	13	5.7	13	5.7	13	5.7
10	11	6.0	12	6.5	12	6.5	12	6.5	12	6.5
11	9	5.9	10	6.6	11	7.3	11	7.3	11	7.3
12	8	6.3	9	7.1	10	7.9	10	7.9	10	7.9
13	6	5.5	7	6.5	9	8.3	9	8.3	9	8.3
14	4	4.3	5	5.4	7	7.5	8	8.6	8	8.6
15	3	3.7	4	4.9	5	6.2	6	7.4	7	8.6
16	2	2.8	3	4.2	4	5.6	5	7.0	6	8.4
17	1	1.6	2	3.2	3	4.7	4	6.3	5	7.9
18			1	1.8	2	3.5	3	5.3	4	7.1
19					1	2.0	2	3.9	3	5.9
20							1	2.2	2	4.4
21									1	2.4
Totals	118	56	128	66	139	80	146	91	153	103
	D.b.h.	Logs	D.b.h.	Logs	D.b.h.	Logs	D.b.h.	Logs	D.b.h.	Logs
Mean "ideal" mt. ht.	11	1	11	1½	11	1½	11	2	11	2
	12+	1½	12+	2	12-13	2	12-13	2½	12-13	2½
					14+	2½	14+	3	14+	3
Mean "ideal" volume bd. ft. per acre	2600		4375		6540		9400		11,525	
Mean "ideal" growth/1 bd. ft. per acre per year	150		230		350		570		640	

/1 Using stocking and merchantable heights in this table and the assumed diameter growths in table ~~26~~. 25

Table 25.--Basis for growth assumptions of "ideal" stand

Site-type class	Mean mt. ht. actual trees	Actual mean diameter growth sawtimber trees: 10 years	Actual mean diameter growth sawtimber trees: Years for 1 inch growth	Actual mean growth dominants. Years for 1 inch growth	Assumed growth attainable "ideal" stand. Years for 1 inch growth /1
	Logs	Inches	Years	Years	Years
M.H. 90+	$2\frac{1}{4}$	1.70	5.9	5.5	4
M.H. 81-89	$2\frac{1}{4}$	1.86	5.4	5.5	4
M.H. 70-80	1-3/4	1.26	7.9	5.5	5
O.H. 65-75	$1\frac{1}{2}$	1.10	9.1	7.4	5
O.H. less 65	$1\frac{1}{2}$	1.04	9.6	7.4	5

/1 Diameter growth used to calculate growth in table 24.

"Ideal" cu. ft. growth has not been calculated. Total cu. ft. current growth represents the growth potential of the site, and it would not vary significantly whether stocking was optimum or whether stands were overstocked. It would be wood material, but much of it would be placed on "wolf" trees, defective trees, limbs, and other places where it could not be used except for fuelwood. Table 5 shows the merchantable cu. ft. volume growth found for the five sites.

At first glance it may appear that the total number of trees per acre in table 24 does not differ greatly for the five site-types. The reason for this is that these differences occur in the larger sizes. For example, the best site-type has five 17-inch trees per acre while the poorest has only one. The relative basal area differences is a better measure of the site-types than number of trees.

If trees larger than shown in table 24 are to be grown on the various sites, it is obvious from this table and from figures 10 and 11 that either the basal would have to be considerably more or that some sacrifice would have to be made in smaller diameter classes. It is not believed on the basis of evidence presented that larger basal areas are desirable on the sites encountered in this study. Therefore, the trees in the smaller diameter classes would have to be sacrificed. From the standpoint of the whole stand, it is difficult to see just where this sacrifice might be made. It has been shown that trees from 16 to 19" are making the most rapid value increment. Trees in the ingrowth class also make very large quantitative board foot contributions to the stand. Perhaps some trees in the class from 12 to 15" could be sacrificed to make space for more large trees in case a convenient furniture veneer market existed and the site was

suitable for growing high quality veneer logs. It requires over three 13" trees to equal the basal area of one 26" tree. In the light of the previous discussion on furniture veneer trees there is considerable question regarding the economics of growing 26" from pole sizes at the slow growth rate desired by veneer manufacturers. As already stated, existing veneer quality trees of 20-22 inches may well be left to grow 24" or 26" (white oak) to obtain maximum veneer prices.

Table 26 presents a hypothetical "veneer" or premium sawtimber stand with a rotation of about 175 years on a 90+ foot site-type. Figure 12 shows the basal area distribution of such a stand. This should be compared to table 24 and figure 11 to see the contract between these two types of stands. Both are uneven-aged, but one has a 175 year rotation and the other about an 85 year rotation. The "veneer" stand sacrifices trees from the 10 through the 17 inch class for an increase in basal area from the 19 through the 27 inch classes. From 17 inches d.b.h. the basal area rises sharply. The volume of the "veneer" stand is 1.8 times as much, but the board foot growth per acre per year is only 0.7 times the corresponding amounts for the "ideal" sawtimber stand. Another point, so far only touched upon in this report, is that the uniformly fast growing hardwoods will be of much higher density and quality for lumber products than slow growing trees in a more heavily stocked stand.

It is clear that a fully-stocked forest stand cannot contain a number of trees over 20 or 21" in diameter (on the best sites) without sacrificing growth on smaller diameter classes. It is up to the forest manager to do some careful figuring before leaving such large trees at the expense of

Table 26.--Hypothetical stand with harvest objective of furniture veneer trees; assuming constant growth of 1 inch in diameter every 7 years; 90' foot site [1]

D.b.h.	Trees	Basal area	Mt. height	Volume	Growth per tree per year	Growth per year
Inches	Number	Sq. ft.	Logs	Bd. ft.	Bd. ft.	Bd. ft.
5	17	2.3				
6	16	3.1				
7	15	4.0				
8	14	4.9				
9	13	5.7				
10	11	6.0				
11	9	5.9	2	630	10.0	90.0
12	7	5.5	2½	686	4.0	28.0
13	5	4.6	2½	600	3.1	15.5
14	5	5.4	3	810	6.0	30.0
15	4	4.9	3	776	4.6	18.4
16	4	5.6	3	904	4.6	18.4
17	4	5.3	3	1,048	5.1	20.4
18	4	7.1	3	1,188	5.0	20.0
19	4	7.9	3	1,348	5.7	22.8
20	4	8.5	3	1,508	5.7	22.8
21	4	9.6	3	1,688	6.4	25.6
22	3	7.9	3	1,401	6.4	19.2
23	3	8.7	3	1,551	7.1	21.3
24	3	9.4	3	1,701	7.1	21.3
25	3	10.2	3	1,878	8.4	25.2
26	3	11.1	3	2,052	8.3	24.9
27	2	8.0	3	1,490	8.7	17.4
Totals	157	152		21,259		441

[1] Actual plots on 90' sites with 129 sq. ft. basal area and 14,960 bd. ft. volume and grew 1 inch in diameter every 5.9 years.

Basal Area Curve of Hypothetical Furniture Veneer or Large Sawlog Stand;

90/ Foot Site-Type

Data from Table ~~25~~ 26

Figure 12

growth of the whole stand, or by sacrificing basal area of trees of smaller diameters. For the production of sawlogs there certainly is no justification for increasing the basal area of trees over 21" at the expense of trees from 16 to 19". If trees grown at a uniformly fast rate for sawlogs can be "converted" to veneer trees by letting them grow another 4 to 6", this would be good business. For sawlogs alone the data and discussion presented tend to show that there is no justification for leaving any trees larger than about 21" on the best sites and not larger than 17" on the poorer sites.

CONCLUSIONS

The following brief numbered statements are the chief and most significant conclusions of this study. The large amount of data in the tables gives related facts and supporting detailed information for these main conclusions.

1. Stands studied were the best that could be found. They were approximately fully-stocked forests but unmanaged. Stands with optimum stocking for sawtimber production were not located and the stands studied were most valuable in showing principles rather than acting as patterns to be copied. A distinction is made between fully-stocked and optimum stocked stands.
2. Analysis of data showed that from the standpoint of obtaining maximum quality board foot growth per acre per year the stands were overstocked.
3. The data showed that there are great differences of site carrying capacity between the mixed hardwoods and oak-hickory types and between site classes within types.

4. On the basis of data obtained, five site-type classes were distinguished and identified by the height of the dominant trees (after height growth had virtually ceased). These five site-types are closely correlated with site index stand volume, basal area, growth, and tree size. They are proposed as working site-types to be recognized in management.

5. The diameter distribution of plots studied was similar to uneven-aged stands but some plots tended to be even-aged plus or minus 20 years. The majority of the stands were two-aged or uneven-aged. The large effect of site overshadowed differences in tree size, stand volume, or basal area due to age.

6. Stands are now overstocked through closing-in and leveling off of growth of individual trees in the unmanaged and uncut (since about 1895) forests.

7. Species composition could be improved by reduction of scarlet oak, black gum, and hickory in sawtimber sizes and by increasing white oak and yellow poplar. Pole sizes in mixed hardwoods contained too much hard maple and hickory, and too little yellow poplar and white oak.

8. There is a consistent relationship by site-types between stand volume, basal area, growth and site index. For fully-stocked stands cubic growth and volume may be estimated from the basal area, if the site is identified. The ratios given would probably apply about as well to managed optimum stocked stands.

9. Diameter growth of the trees studied is highly correlated with crown class. Within crown classes there is little or no correlation between diameter growth and diameter, as such.

10. The ratio between diameter growth and diameter for different crown classes is a constant, about 10. This shows that any given tree has tended to stay in about the same crown class throughout most of the life of the stand.

11. In the fully-stocked unmanaged stands individual dominant and co-dominant trees over 13.5" d.b.h. are growing less board feet per tree per year for each successive 2 inch diameter period. This is a result of increased competition and closing-in of the stand. It is the strongest evidence that the stands studied are overstocked from the standpoint of board foot growth on the best trees. An example is given of a 9" white oak aged 80 years which illustrates the principle.

12. From the standpoint of volume alone growth on 2.5 to three 11-13 inch trees, if released, will equal or exceed the growth on one 20-26 inch tree plus the former growth of the smaller trees. Trees on the better mixed hardwoods sites have reached volume maturity when about 20-22" d.b.h. On poorer sites it would be correspondingly less.

13. On the basis of board foot volume growth in uneven-aged stands in relation to basal area occupied, trees of even 20 inches make a poor showing in relation to smaller trees.

14. Considering log grades alone and using current log prices by grades, the value per thousand board feet of logs or stumpage shows the greatest value increment in the period 16 to 19 inches d.b.h. of the tree. At about 19 inches the value per M levels off.

15. Lumber value per M based on grade recovery increases with tree size beyond 19 inches d.b.h. and up to 30 inches or more. This added value of lumber recovered should be, but often is not, reflected in value of the stumpage based on log grades.

16. Based on assumed constant diameter growth of individual trees from 11 to 30 inches d.b.h. the steepness of the stumpage and lumber value curves is greatest from 16 to 19 inches d.b.h. After about that point the steepness of the basal area curve is greater than the growth or value curves.

17. Simple interest earned from such constant diameter growth trees falls below 3 percent at 20 inches on the best site and below 2 percent at 21 inches on medium and poor sites.

18. On constant diameter growth trees the relation between board foot growth and basal area is the same as that between the perimeter and the area of a circle. Comparing a 19 and 30 inch tree on the best site, the yearly board foot growth is 1.6 times greater on the larger tree, but basal area is 2.5 times greater.

19. If replacements are available for trees cut, as in an uneven-aged managed stand, the simple interest of about 1.5% earned by 30 inch trees on good sites can be converted into a 3 or 4 percent earning by putting the extra growth on 15 to 19 inch trees.

20. All the present data combined place economic maturity of sawtimber trees of good species at about 20-21 inches on the better sites and 17 inches on the poorer sites. This is based on volume growth as related to stand growth, value of the growth, and interest earned by growth.

21. The conclusions regarding furniture veneer trees are as follows: (a) white oak should not be grown beyond 28" d.b.h. and yellow poplar and red oak beyond 24" for veneer; (b) existing 20-22 inch sound healthy trees of veneer quality on good sites should be left to grow to veneer size if growth need not be slower than 15-20 rings per inch and especially if more rapid growth is acceptable; and (c) growing veneer trees from poles at 20 or even 15 rings to the inch will return a very low rate of interest on the investment.

22. A study of the structure of the fully-stocked unmanaged stands shows some of the undesirable features and weaknesses of such stands. These are listed in the text.

23. Five "ideal" managed stands are set up, one for each of the five site-types already explained. The hypothetical stand values include number of trees per acre, diameter distribution, merchantable height, basal area, volume, and growth. They are proposed as temporary goals of management for sawtimber until better data are obtained through actual management of experimental stands. The key ideas are that basal areas must be adjusted or reduced mainly by the elimination of the largest trees, diameter distribution should be evened up, merchantable heights must be increased by elimination of the poorer trees, and carrying capacity of site-types considered as an essential factor in management plans.

24. A hypothetical stand for furniture veneer or very long rotation sawtimber is set up and compared with the proposed "ideal" sawtimber stand.

RECOMMENDATIONS

These recommendations are given as guides for converting the upland forests of southern Illinois from an unmanaged to a managed condition. A managed condition includes optimum stocking and basal area for growth of products desired, proper diameter distribution and species composition, and individual trees of maximum merchantable height and quality of form. The principle of recognized site-type carrying capacity is an essential feature of the following recommendations based mostly on data from this study but in small part on another study [8] already completed.

1. The unmanaged stands should have one or more improvement cuts to eliminate all culls and all trees with a poor future because of defects or poor form.

2. In mixed hardwood stands discriminate against black gum and all except the very best hickory. Watch scarlet oak carefully for poor quality and defect and keep it to a short rotation. Among pole sized trees discriminate especially against hard maple, beech, hickory, and sassafras. Favor yellow poplar, white oak, northern red oak, black oak, and well-formed individuals of black walnut, black cherry, and white ash.

3. In oak-hickory stands discriminate against hickory and blackjack oak. Favor white oak and black oak on the better sites and black oak, southern red oak, and post oak on the poorer sites. Favor scarlet oak only as a short rotation species.

[8] Minckler, L. S., Fassnacht, D. L., and Train, R. K. 1948. Growth and species evaluation of some unmanaged upland hardwoods in southern Illinois. Tech. Paper No. 110. Central States Forest Exp. Sta.

4. Recognize site-types as an essential basis for management. The five site-types used in this report are logical for the hilly uplands of southern Illinois but others may be better adapted to different regions.

5. Gradually bring unmanaged stands to a managed condition according to the tentative site-type management goals set up in table 24 of this report. This may involve either a reduction of stocking (as in the case of most of the plots studied) or a building up of stocking to the optimum for the site.

6. If stands are fully-stocked or overstocked, improve the stand and reduce the basal area by the following types of cutting: (a) improvement cut, (b) cut to improve species composition, (c) cut of trees larger than maturity limit for site, and (d) cut of short-boled trees. If further reduction is needed, make cut to improve diameter distribution. In most cases, diameter distribution correction will require at least four or five cutting cycles.

7. If stands are understocked, make rehabilitation cut to eliminate all undesirable elements, make provision for reproduction if needed, and wait for growth to build stocking to optimum for site, making thinnings and improvement cuts as required. The rehabilitation cut should include (a) culls of all sizes, (b) poor future trees due to defect or form, (c) mature trees which are competing with desirable smaller timber or reproduction, and (d) the worst of the poor species and short-boled trees. It is better to reduce basal area considerably below optimum than to have the site

occupied by worthless or poor future trees. In hardwood forests which are not overstocked and which are protected from fire and livestock, reproduction is characteristically plentiful.

8. Diameter distribution should be gradually corrected over a fairly long period of time by discrimination against overstocked diameter classes.

9. Cutting cycles should be governed by operable cut and growth. The basal area will fluctuate below and above the optimum, depending upon the intensity of the cut. On the better sites the basal area should not be reduced by cutting more than 15 below optimum or allowed to grow more than 10 above optimum. On the poorer sites this range should be held to 10 below and 5 above.

   Assuming a certain operable cut, growth (site quality) will determine length of cutting cycle. For example, a reduction of 10 in basal area taken in economically mature trees on the better site-types would be about 1500 bd. ft. Int. According to table 24 the best site would re-grow this in a little over two years, the next best in about three years, etc. On the best site a one-year cutting cycle could remove 650 bd. ft. per acre each cut. On the poorest site a four-year cycle would be required for a 600 bd. ft. cut.

10. The recommendation on limits of tree maturity are included in the "ideal" stand in table 24. This is based on growth in relation to the remainder of the stand and quality of that growth. Sawtimber tree economic maturity is stated to be from 17 to 21 inches d.b.h., depending upon site-type. Existing high quality furniture veneer

trees of 20-22" d.b.h. may be left to 26-28" d.b.h. for white oak and 24" for yellow poplar and red oak, if growth rate need not be slower than 15-20 rings to the inch.

11. The forest manager should govern quality and texture of timber grown by management practices. The "ideal" stands set up, and the application of the principles governing cutting intensity and cutting cycles discussed above, should result in approximately uniform growth rings throughout the life of sawtimber sized trees until they are cut.

12. Finally, it is recommended that the continuous inventory system of control be adopted as a necessary tool of intensive management. Without inventories including species, d.b.h., and merchantable height, the attainment of the optimum stand structure and maximum quality growth is impossible, or at best largely guesswork. On tracts up to about 40 acres a 100 percent inventory is best and probably the cheapest in the long run. On larger tracts a sound and adequate system of sampling would be satisfactory. Inventories should be made before each cut and may sometimes be combined with marking and a cut and leave tally.

Appendix Table 1. Sample Field Data Sheet

OBJECTIVE STUDY

o. 8 Small plot - 1/10 A. Field work by: Minckler & Train Date 10/24/47

ct East Slope % 20 Topographic position Whole of short slope

t type M.H. History Essentially virgin stand, no cutting or recent fires

ecies	D.B.H. Inches	Merch. height feet or logs	Culls	Dead	Total height feet	Radial growth - 1/20 in. 5 yrs.	10 yrs.	15 yrs.	20 yrs.	Radial bark thick. inches	Crown class	Age years
.	25.7	3	-	-	85 Dead top	2	4	6	9	0.90	D	
.	13.4	1½	-	-	-	1	3	5	7	0.65	I	
.	15.1	2	-	-	-	7	14	20	27	0.55	CD	
.	11.5	1½	-	-	-	8	17	25	33	0.50	I	
.C.	5.4	12	-	-	-	1	2	5	8	0.30	S	
.C.	5.8	12	-	-	-	1	3	5	8	0.20	S	85
.C.	9.3	28	-	-	-	7	13	19	26	0.30	I	
.	15.7	2½	-	-	80	8	16	24	32	0.70	CD	
.	26.1	3	-	-	85	6	12	20	30	1.10	D	
.	16.1	2	-	-	-	6	15	23	32	.75	CD	
.C.	21.3	2½	-	-	-	8	16	24	32	1.10	D	
	8.0	16	-	-	-	2	4	7	11	0.35	S	105-110
sh	5.5	-	Yes	-	-					0.50		55
.C.	7.9	12	-	-	-	2	4	6	10	0.30	I	65
.O.	20.0	2	-	-	-							
.O.	12.1	2	-	-								
.O.	7.9	20	-	-								
.O.	5.4	8	-	-								
.M.	5.7	12	-	-								
.O.	13.4	1½	-	-								
.O.	7.5	16	-	-								
.O.	9.0	24	-	-								
.O.	21.0	2	-	-								
.O.	7.4	-	Yes	-								
.O.	15.1	2	-	-								
.O.	12.5	1½	-	-								
.O.	12.0	2	-	-								
.O.	5.7	12	-	-								
	5.2	12	-	-								

Appendix Table 2. Sample Field Data Sheet

OBJECTIVE STUDY

Species	D.B.H. inches	No. yrs. 1 in. radial gr.			Logs by log grades Length ft. & D.I.B. in.			
		Out-side	Next inside	Third inside	Prime	No. 1	No. 2	No. 3
Y. P.	25.7	33	14	14		16-20 16-18		16-15
W.O.	15.1	15	15	10			14-12	8-11 8-9
W.O.	15.7	12	12	8			16-12	14-10 8-9
B.O.	26.1	15	9	8		16-20 16-18		12-15
W.O.	16.1	13	11	9			16-13	14-11
W.O.	21.3	12	13	11		16-17	16-15	8-13

Appendix Table 3. Form Classes Used for Volume Calculations [1]

Diameter class	All oaks except post	Hickory and post oak	Yellow-poplar	Other species
	Form class [2]			
5- 7"	65	55	74	65
8-10"	76	70	76	70
All sawtimber	76	76	76	76

[1] Used following volume tables; all board foot volumes International ¼-inch

Sawtimber volume, bd. ft. Tables for Estimating Board-Foot Volume of Timber, by Clement Mesavage and James W. Girard.

Total volume, cu. ft. Tables for Estimating Cubic-Foot Volume of Timber, by Clement Mesavage, Occ. Paper No. 111, Southern Forest Exp. Sta.

[2] As defined in the above two publications.

Appendix Table 4. Values Used for Projecting Merchantable Heights into the Past/1

Diameter class	Mixed hardwoods type				Oak-hickory type		
	Oaks and hickory	Yellow-poplar	Hard maple	Other	Oaks	Hickory	Other
	Merchantable height, feet						
5	12	12	8	12	8	8	8
6	16	16	12	16	16	12	12
7	20	24	16	20	24	20	20
8	24	32	20	24	28	24	24
9	28	36	24	28	28	28	28
10	32	40	24	32	28	28	28
Sawtimber/2	-	-	-	-	-	-	-

/1 Taken from curves of estimated Mt. Ht. in 4-ft. lengths (to 4 inch top for poles) over D.B.H. inches.

/2 Sawtimber Mt. Ht. by half-log lengths showed no relation to D.B.H. except that no 11 inch tree had over 2 16-ft. logs. Only one tree had over 1½ logs.

Appendix Table 5. Double Bark Thickness [1] Used in Growth Calculations

D.B.H.	Species									
	White oak	Bl. & So. R. oak	Scarlet oak	Nor. R. oak	Post oak	Hickory Elm	Yellow-poplar	Black gum	Black walnut	Hard maple B. Cherry
Inches	Inches at breast high									
5	.43	.73	.57	.53	.88	.65	.51	.55	.72	.36
6	.52	.81	.63	.61	.93	.74	.60	.66	.85	.44
7	.61	.88	.69	.69	.98	.83	.72	.77	.99	.52
8	.70	.96	.75	.78	1.03	.92	.78	.89	1.12	.60
9	.79	1.04	.81	.86	1.08	1.01	.87	1.00	1.26	.69
10	.89	1.11	.87	.94	1.13	1.10	.96	1.12	1.40	.77
11	.97	1.19	.93	1.02	1.18	1.19	1.05	1.23	1.54	-
12	1.06	1.26	.99	1.10	1.23	1.28	1.14	1.35	1.67	-
13	1.15	1.34	1.05	1.19	1.28	1.37	1.23	1.46	1.81	-
14	1.25	1.41	1.11	1.27	1.33	1.46	1.32	1.58	1.95	-
15	1.34	1.48	1.18	1.35	1.38	1.54	1.41	1.69	2.08	-
16	1.43	1.56	1.24	1.43	1.43	1.63	1.50	1.81	2.22	-
17	1.52	1.63	1.30	1.51	1.48	1.72	1.59	1.92	2.36	-
18	1.61	1.71	1.36	1.60	1.53	1.81	1.68	2.04	2.50	-
19	1.71	1.78	1.42	1.68	1.58	1.90	1.77	2.15	2.63	-
20	1.80	1.86	1.48	1.76	1.63	1.99	1.86	2.27	2.77	-
21	1.89	1.94	-	1.84	-	2.08	1.95	-	-	-
22	1.98	2.01	-	1.92	-	2.17	2.04	-	-	-
23	2.07	2.08	-	2.00	-	2.25	2.13	-	-	-
24	2.16	2.16	-	2.09	-	2.35	2.22	-	-	-

[1] Calculated from data collected in southern Illinois.

Appendix Table 6. Sample Growth Calculation; Plot 1

Species	Present D.B.H.	Present Mt. Ht.	Present D.i.b.	Diameter growth 10 yrs.	D.i.b. 10 yrs. ago	D.B.H. 10 yrs. ago	Mt. Ht. 10 yrs. ago	Present volume	Volume 10 yrs. ago	Growth 10 yrs.	Cubic Volume: Present	Cubic Volume: 10 yrs. ago
Sawtimber		Logs or feet	Inches	Inches	Inches	Inches	Logs or feet	Bd.ft. Int.	Bd. ft.	Bd. ft.	Cu. ft.	Cu. ft.
B.O.	17.9	2	16.2	2.0	14.2	15.7	2	221	169	52	32.8	25.9
B.O.	15.4	1½	13.9	1.1	12.8	14.2	1½	116	99	17	17.8	15.3
B.O.	18.9	2	17.1	2.3	14.8	16.4	2	250	169	81	36.8	25.9
B.O.	17.0	1½	15.4	2.4	13.0	14.4	1½	154	99	55	23.0	15.3
B.O.	16.2	1½	14.6	1.3	13.3	14.8	1½	134	116	18	20.4	17.8
Hickory	10.6	1	9.4	1.0	8.4	9.4	16	43	0	43	7.0	4.7
B. Wal.	11.4	1½	9.9	1.5	8.4	9.8	24	56	0	56	9.6	7.3
B. Wal.	12.3	1	10.6	2.2	8.4	9.8	16	52	0	52	8.2	5.7
									Total	374/1	155.6	117.9
									Growth	223	Growth	37.7
									In-growth	151		
Poles												
Hickory	6.7	28	5.9	1.1	4.8	5.4	20				2.7	1.2
Hickory	6.1	16	5.4	0.5	4.9	5.6	16				1.4	1.4
H. Map.	5.9	12	5.5	1.0	4.5	4.8	8				1.4	0.7
H. Map.	7.0	16	6.5	1.4	5.1	5.5	8				2.4	0.7
H. Map.	6.7	16	6.2	1.5	4.7	5.0	8				2.4	0.7
H. Map.	4.9	8	4.5	0.6	3.9	4.3	0				0.7	0
											11.0	4.7
											Growth	6.3
									Total	cu. ft.	growth	44.0/1

/1 Growth on 1/10 acre for 10 yrs. or on 1 acre per year.

Appendix Table 8. Site Descriptions of Plots

Plot No.	Aspect	Slope Percent	Topo. Position	History	Location	Height Dom. trees
Mixed Hardwoods Type						
1	North	25	Head of cove	Partially cut 1893	Easterly tract 5 mi. SW. Carbondale	70
2	East	10	Middle slope	Partially cut 1893	Easterly tract 5 mi. SW. Carbondale	75
3	North	15	Lower slope and stream margin	No cutting for at least 50 yrs.	Robinson tract 5 mi. NW West Vienna	90
4	North east	20	Lower slope and cove	No cutting for at least 50 yrs.	Catone tract 3 mi. W Cobden	92
6	North	10	Cove and lower slope	No cutting for at least 50 yrs.	Shawnee N. F. East Stonefort	80
8	East	20	Lower slope	Virgin	Kaskaskia Exp. For. Natural area	85
10	-	Flat	Narrow cove and lower slopes	Partially cut about 1890-1900	Just west Kaskaskia Near Hicktown	80
11	North east	20	Lower slope	Partially cut about 1890-1900	Kaskaskia Minimum Cutting demonstration	82
16	-	Flat	Cove and stream margins	No cutting for at least 50 yrs.	Near Bay City on Ohio River	90
19	South	5	Cove	Never cut heavily. No cutting for at least 60 yrs.	Wilson's Woods Karber's Ridge	75
Oak-Hickory Type						
5	South	25	Lower slope	Never cut heavily. No cutting for at least 50 yrs.	Shawnee N. F. East Stonefort	75
7	South east	10	Flat ridge top	No cutting for at least 50 yrs.	Union State Forest	65
9	South west	20	Lower spur ridge	Partially cut 50-60 yrs. ago	West Kaskaskia Hicktown	60
12	South west	12	Lower spur ridge	Partially cut 1890-95	Kaskaskia Minimum Cutting demonstration	67
13	South west	15	Ridge and upper slope	Partially cut about 40-50 yrs. ago	Kaskaskia "Good" Farm Woods	Pole stand
14	South east	10	Ridge and upper slope	Partially cut about 1890-1900	Kaskaskia "Good" Farm Woods	70
15	South	25	Middle slope Very rocky	No cutting for at least 50-60 yrs.	Kaskaskia Section 34	Pole stand
17	-	Flat	Ridge top	No cutting for at least 50-60 yrs.	15 mi. north Metropolis along Route 145	62
18	South	12	Lower spur ridge	Never cut heavily, No cutting for at least 60 yrs.	Wilson's Woods Karber's Ridge	65
20	South west	40	Upper slope	Partial cutting 1890-1900	Kaskaskia Fowler tract	60

Appendix Table 7. Sample Calculation; Individual Tree Growth by Diameter Class Periods

Species	D.B.H.	Mt. height	Rings per radial inch: Outside inch	Rings per radial inch: next inside inch	Rings per radial inch: Third inch
	Inches	Logs	No. years for 2-inch diameter change		
Black oak	17.9	2	10	9	6
"	18.9	2	9	8	7
"	17.0	1½	8	9	8
"	16.2	1½	15	12	10
"	17.3	1	14	11	10
"	17.6	2	10	10	10
"	17.5	2	12	10	8
"	16.5	2	14	9	9
"	17.6	1½	17	12	9
"	16.8	2½	8	7	7
"	14.7	3	17	11	9
"	15.4	1½	17	10	8
Means	17	2	13	10	8

D.B.H.	Mt. Ht.	Volume
Inches	Logs	Bd.ft.
17	2	195
15	2	146
13	2	104
11	1½	56

D.B.H. change	Volume change	Time required	Growth per year	Growth per year
Inches	Bd. ft.	No. yrs.	Bd. ft.	Percent
15-17	49	13	3.77	2.58
13-15	42	10	4.20	4.04
11-13	48	8	6.00	10.70

Appendix Table 9. Forest Products Laboratory Log Grades

Specifications for Grading Hardwood Sawlogs in the Central States

Requirements for the three best faces

Log grade	Log diameter	Position of log	Log length	Clear cuttings 2/: Minimum portion of log length	Clear cuttings 2/: Maximum number	Clear cuttings 2/: Minimum length	Allowable sweep	Allowable cull
	Inches		Feet			Feet	Percent	Percent
1	13-15	Butt				7		
	16-19		10+	5/6	2	5	15	40
	20+	Any				3		
2	10		10+	5/6	2	7		
	11+		10&11	2/3			30	50 1/
	11+	Any	12+		3	3		1/
	12+		8 & 9	3/4	2			1/
3	8+	Any	8+	-	-	-	-	66-2/3%

1/ No. 1 logs degraded because of cull deductions will permit 60 percent cull.

2/ Definitions:

Cutting. - That clear portion of any face of a log extending for the entire face width either between the end of the log and a defect, or between defects.

Face. - One-fourth of the circumference of the log, longitudinally, as viewed by the grader.

Defect. - Any irregularity or imperfection in the log which lowers the utility of the lumber when sawed. Common defects visible on the surface of the log which limit length of cuttings are knots, branches, bumps, burls, or their indications.

Forest Products Laboratory
Madison, Wisconsin
September 18, 1947

SPECIAL PROVISIONS

No. 1 Log Grade. - Mineral stain in maple, dote in birch and other nondeductible interior defects in any species are limited to a diameter one-half the small end diameter of the log.

Sweep in logs having one-fourth or more of the small end diameter in interior defects is limited to 10 percent of the gross scale.

No. 2 Log Grade. - Logs 10 inches to 15 inches limit interior defects to one-half the small end diameter of the log; 16 inches or larger will admit three-fifths or 60 percent.

Sweep in logs having one-fourth or more of the small end in interior defects is limited to 20 percent of the gross scale.

All Oak Species

No. 1 Log Grade - 14 inches minimum diameter
No. 2 Log Grade - 11 " " "

Beech

No. 1 Log Grade - 15 inches minimum diameter

Forest Products Laboratory
Madison, Wisconsin
Sept. 18, 1947

Appendix Table 10. Simplified and Rearranged Forest Products Laboratory Log Grades

	Length	Diameter i.b. 1/ small end	Requirements for 3 best faces: Clear cuttings		
			Portion	Max. No.	Min. Length
	Feet	Inches			Feet
Grade 3 Cull 66.7% or less	8+	8+	-	-	-
Grade 2 Cull 50% or less and sweep 30% or less	10+	10	5/6	2	7
	10&11	11+	4/6	2	3
	12+	11+	4/6	3	3
	8 & 9	12+	3/4	2	3
Grade 1 Cull 40% or less and sweep 15% or less	10+	13-15(butt)	5/6	2	7
	10+	16-19	5/6	2	5
	10+	20+	5/6	2	3

1/ In grades 2 and 1 the given diameters must be increased one inch for all oak species. Beech diameter must be at least 15 inches for grade 1.

Adapted from:
Forest Products Laboratory Log Grades
Sep. 18, 1947.

Appendix Table 11. Taper Table Used for Assistance in Determining Log Grades and Sizes 1/

Tree D.B.H. class	D.i.b. at 2/ 17 ft.	D.i.b. class 17 ft.	Possible log grades		
			Beech	Oaks	Other Species
Inches	Inches	Inches	16 ft. butt logs		
11	8.4	8	3	3	3
12	9.1	9	3	3	2, 3
13	9.9	10	3	3	2, 3
14	10.6	11	2, 3	2, 3	2, 3
15	11.4	11	2, 3	2, 3	2, 3
16	12.2	12	2, 3	2, 3	2, 3
17	12.9	13	2, 3	2, 3	1, 2, 3
18	13.7	14	2, 3	1, 2, 3	1, 2, 3
19	14.4	14	2, 3	1, 2, 3	1, 2, 3
20	15.2	15	1, 2, 3	1, 2, 3	1, 2, 3
21	16.0	16	1, 2, 3	1, 2, 3	1, 2, 3
22	16.7	17	1, 2, 3	1, 2, 3	1, 2, 3
23	17.5	17	1, 2, 3	1, 2, 3	1, 2, 3
24	18.2	18	1, 2, 3	1, 2, 3	1, 2, 3
25	19.0	19	1, 2, 3	1, 2, 3	1, 2, 3
26	19.8	20	1, 2, 3	1, 2, 3	1, 2, 3

1/ Taper rule of thumb used: ½ inch d.i.b. for each 4 foot of log length. Not used for stem portions above large limbs.
2/ Calculated for form class 76.

Appendix Table 12. Sample Calculation of "Ideal" Growth in Table 24; Type O-H, Site 65-75

D.B.H. now	D.B.H. 10 yrs. ago	Mt. Ht. now	Mt. Ht. 10 yrs. ago	Volume now	Volume 10 yrs. ago	Growth per tree	Trees per acre	Growth per diameter class
Inches	Inches	Logs	Logs	Bd. ft.	Bd. ft.	Bd. ft.	Number	Bd. ft.
18	16	2	2	221	169	52	1	52
17	15	2	2	195	146	49	2	98
16	14	2	2	169	124	45	3	135
15	13	2	2	146	104	42	4	168
14	12	2	2	124	85	39	5	195
13	11	2	1½	104	56	48	7	336
12	10	2	0	85	0	85	9	765
11	9	1½	0	56	0	56	10	560

Total growth 10 yrs. 2309 per acre
Growth 1 yr. 231 per acre